STRETCHING WATER SUPPLIES

Alternate Technologies and Strategies

Edited by Don T. Waite

Angela Lucas is a Saskatchewan artist who specializes in medieval art forms and illuminated texts. Her compositions, which use traditional materials such as vellum, gold leaf and hand-prepared pigments, have been shown internationally. The cover of this symposium illustrates some uses of water. The original ink drawing was made with a feather quill and the style is eleventh to twelfth century.

Stretching Water Supplies

Alternate Technologies and Strategies

Stretching Water Supplies

Alternate Technologies and Strategies

Proceedings of the Seventh Biennial Plains Aquatic Research Conference

Edited by Don T. Waite

Canadian Plains Research Center
University of Regina
1992

Copyright © Canadian Plains Research Center

Copyright Notice

All rights reserved. No part of this book covered by the copyrights hereon may be reproduced or used in any form or by any means — graphic, electronic or mechanical — without the prior written permission of the publisher. Any request for photocopying, recording, taping or information storage and retrieval systems of any part of this book shall be directed in writing to the Canadian Reprography Collective, 379 Adelaide Street West, Suite M1, Toronto, Ontario M5V 1S5.

Canadian Plains Research Center
University of Regina
Regina, Saskatchewan S4S 0A2
Canada

∞
Printed on acid-free paper

Canadian Cataloguing in Publication Data

Plains Aquatic Research Conference (7th : 1991 ;
University of Regina)

Stretching water supplies

(Canadian plains proceedings, ISSN 0317-6401 ; 24)
ISBN 0-88977-073-5

1. Water-supply – Prairie Provinces – Congresses.
2. Water-supply – Great Plains – Congresses.
3. Water conservation – Prairie Provinces – Congresses.
4. Water conservation – Great Plains – Congresses.
I. Waite, Don T. II. University of Regina. Canadian Plains Research Center. III. Title. IV. Series.

TD227.P7P52 1991 333.91'009712 C92-098156-9

Cover Design: Angela Lucas
Printed and bound in Canada by Hignell Printing, Winnipeg, Manitoba

93-00966/

Contents

Introduction

Don T. Waite vi

Characteristics of Water Supplies and Sources in the Great Plains

R.B. Godwin 1

Technologies and Strategies Used to Develop and Access Water Supplies on the Great Plains: Water-Quality Considerations

P. Tones and R.S. Pentland 16

Technologies and Strategies Currently Used to Develop or Access Water Supplies: Water-Quantity Considerations

R.S. Pentland and P. Tones 34

Alternate Technologies and Strategies to Stretch Existing Water Supplies in the Great Plains: Water-Quantity Considerations

R.S. Pentland and P. Tones 43

Preliminary Analysis of the Feasibility of Water-Conservation Programs in Rural Prairie Communities

Brian T. Abrahamson, Gordon K. Kerster and Donald M. Tate 50

Strategies to Motivate Water Users and Managers to Adopt Alternate Technologies

Larry J. Whitney 64

Contributors 70

Introduction

Water management practices on the Prairies can often be summed up as "drain it and dam it." Sloughs and wetlands are drained by landowners to produce more farmland. Streams are dammed to store water for future needs. Both activities are politically satisfying as they produce obvious and immediate benefits such as jobs and tangible structures. In the long term, however, these activities may not always be the best strategy for the Prairies.

Wetlands act as slow-release water-storage areas and may contribute to the recharge of surficial aquifers. Dams can only contain water when it exists. During drought, when the watershed is dry, there is nothing to store. Most reservoirs do not have the capacity to retain large enough volumes to supply water for extended drought periods.

The purpose of this symposium was to address current storage practices and to extend current technologies and understandings into the future, searching for new and viable concepts. Godwin described the quality and quantity of water resources in the region. Tones and Pentland, in three papers, outlined current management practices and projected new methods. Abrahamson et al. described the economics and Whitney discussed the problems of persuading people that new methods should be tried.

Following the presentation of these papers at the Plains Aquatic Research Conference (PARC '91), workshop sessions were held to allow general discussion by conference participants. The papers by Tones and Pentland were treated in one of these sessions, and reported on by two rapporteurs. Each other session was described by one rapporteur. The rapporteur's report of the workshop discussions is presented at the end of each section.

Having carried out this exercise it will become apparent to the reader that no new conceptual breakthroughs have been made. Sadly, the state of our technology has not risen to the needs of our prairie society. We, then, challenge you the reader to build on what we have written to carry a revolution in water management into the twenty-first century. If predictions of climatic change are correct, we are going to need it.

Don T. Waite
Regina, Saskatchewan

Characteristics of Water Supplies and Sources in the Great Plains

R.B. Godwin

Water supplies on the Prairies of Canada are a function of the land from which they originate and that land is, in turn, a function of millions of years of geological history. A brief look at the prehistoric events that created this unique region will help us to better understand the nature of the Prairies' water supply characteristics. For this overview, I have used information from the *Geological History of Saskatchewan* (Storer 1989).

GEOLOGICAL BACKGROUND

Some of the initial shaping of the Great Plains occurred in the Precambrian Era but the factors that have had the most effect on its water supply potential started during the Mesozoic Era when a transition between early unfamiliar plants and the more modern flora and fauna occurred. In the Jurassic Period of this era, thick layers of limestones, dolomites, shales and sandstones were deposited in large flat layers. The Cretaceous Period, the age of the dinosaur, followed. It lasted for 79 million years and ended over 70 million years ago. During this period a large saline sea, extending from what is now the mouth of the Mackenzie River to the Gulf of Mexico, covered most of the prairie region. The sea grew and shrank, probably depending upon worldwide ocean levels, and the deposits in this massive sea formed a flat sea bed that later became the Plains of North America. As the Rocky Mountains thrust their way upwards, the sea floor tilted, sloping downwards to the east and the sea moved in the same eastward direction. As land became exposed on the western edge of this sea, extensive sandstone formations were deposited along the shore areas. The McMurray tar sands, the Mannville Group, the Bearpaw, Milk River, Judith River and Frenchman River formations were deposited in this fashion and all of these formations were affected by the saline nature of the sea that created them.

The Mesozoic Era gave way to the Cenozoic Era and, in the Quaternary Period of the Cenozoic Era, four or five sequences of glaciation occurred on the Canadian Plains. During each of these transitional periods, massive icecaps built up and melted. The sedimentary rocks, shales, silts and sands that are immediately below the

surface of the Great Plains were deposited as the glaciers reshaped the land. The most critical glacier in this reshaping process was the last one, the Wisconsinian Glacier. Its southern edge was probably the Missouri River in North Dakota and at its maximum depth it was about 1,000 metres thick. This depth decreased with time until, as it started to melt, it was from 200 to 300 metres thick. The large glacial outwash valleys of the South and North Saskatchewan, Frenchman, Big Muddy, Battle, Souris, Qu'Appelle and Assiniboine rivers and their tributaries were all cut by meltwater flowing from this massive ice sheet.

Two other distinctive features of the Prairies are a distinct result of this melt period. Large glacial lakes such as Glacial Lake Regina in Saskatchewan and Lake Agassiz in Manitoba formed during the melting period and these lakes filled with fine sediments creating the flattest areas in the Prairies. When the water drained it left behind thick, black soils that became the richest agricultural land in the two provinces. The second distinct feature was the numerous potholes left behind after the glacier melted. Massive blocks of ice fell from the glacier during the melting period and these were buried in the moraine at the glacier's southern edge. When the ice melted, the overlying deposits collapsed forming a depression, or kettle, surrounded by low hills or knobs. Hence the phrase "knob and kettle" topography.

HISTORICAL BACKGROUND

The Wisconsinian Glacier melted over 17,000 years ago. A forest composed primarily of black spruce sprang up over the entire prairie area and as the climate became more arid this forest disappeared to be replaced by the grasslands that met the eyes of the first people to inhabit this land.

The Cree and Assiniboine Indians lived on the Prairies and coped with both floods and droughts as a fact of life. They pursued a nomadic existence, following available water supplies and food sources. When drought dried up the more limited water supplies of the Prairies, they migrated to adjacent areas where water was more plentiful. When floods made the wetlands uninhabitable, they moved back to drier areas where the supplies of water and food had been replenished.

A little more than 130 years ago, an Irishman named John Palliser crossed the Canadian Plains with a group of explorers and scientists (SNBB 1972a, 1972b). He classified the Great Plains as a desert area where it would be hard to sustain a continuing stable economy and suggested caution and restraint in its development. In comparison to his native Ireland, that conclusion must have appeared to be valid. Professor H.Y. Hind, from Ontario, also explored a portion of the same area in 1858 and

suggested that, while it was an arid land, it could be developed and farmed.

Some things have not changed. It is still difficult to find enough water to supply current needs in dry years. The houses shut out both the cold and the heat more effectively but new barriers, like world trade balances and the economy, become stumbling blocks. One big change has occurred. The people who live on the Plains are no longer nomadic so permanent water supplies are needed. Fortunately, through the federal and provincial water-resource agencies, more is known about both the nature and the extent of the Prairies' water resources.

Some of the characteristics of these limited water supplies will be described in this paper. The discussion will be broken into four parts: surface water (quantitative considerations); groundwater (quantitative considerations); quality of water (both surface and groundwater); and the relationship of water to the environment The order selected is not a measure of their relative importance but any project assessment that does not include all four of these components in its feasibility studies will be incomplete (Godwin et al. 1990).

SURFACE WATER — QUANTITATIVE CONSIDERATIONS

Streamflow is a residual of precipitation. Rain, or snow, falls to the ground and is absorbed. The moisture that is not absorbed trickles into runoff channels forming creeks, rivers and lakes and these are the surface-water sources that may be developed for use.

In Regina, the centre of the Great Plains area, the average precipitation is 384 mm (based on records from 1951 to 1980 inclusive at the Regina airport) and this average may be subdivided into 287 mm of rain and 97 mm from snow. Because of the aridity of the Plains area most of the rain in the summer is absorbed directly into the ground and does not reappear as runoff. This leaves only the winter precipitation, 116 cm of snowfall with a water equivalent of 97 mm of water in an average year, to contribute to streamflow.

Snow is also affected by the winter climate. The snow that falls in the early winter months is redistributed before spring. It fills ditches and coulees, evaporates in the winter sun, melts into the ground and, in general, deteriorates throughout the winter. In the spring the snow melts and becomes runoff. The runoff water is harvested by the storage reservoirs built to hold that water. After the spring runoff is over, the user can then plan for the coming year, knowing how much, or little, has been made available through the runoff process. In average years, about 10 percent of the snow (10 mm of water) ends up in the creeks and rivers, less than 3 percent of the average annual precipitation in the Regina area.

Drought years acerbate shortage problems and for the past fifteen years below average annual flows have been experienced. As the precipitation decreases, both snowfall and the water subsequently available decrease. In many of the smaller prairie streams there is no runoff in dry years. A rule-of-thumb often used in designing small water reservoirs and dugouts has been to assume that a reservoir should be large enough to survive two years with no additional runoff. Recent droughts, and the drought in the 1930s, suggest that this is not an overly conservative criteria and some dugouts designed on this basis have been dry in recent years.

A look at the annual flow volume in such well-known streams as the Souris, Qu'Appelle, and Frenchman rivers (Historical Streamflow Summary, 1988) shows several consecutive years of below normal flows and some years when streamflow is almost nonexistent. It also shows some flood years when the streamflow is as much as five times the average flow.

In a typical year, on any of these prairie streams, one would expect runoff to start shortly after the snowmelt period has begun, usually from March 15 to April 15, and to increase rapidly to peak flow within ten days. The streamflow will then decrease in a more gradual manner until, by the end of April, the watercourse is again dry. Occasionally these small streams may flow again during the year as a result of rainstorms within the drainage basin but in average years they will stay dry.

Drainage areas in the Prairies add another variable to the runoff patterns (Winter 1989). Much of the land left after the Wisconsinian glaciers melted includes large areas of pot and kettle topography. The drainage in these areas is not continuous. There are large sloughs, potholes and terminal lakes like Old Wives Lake and the Quill Lakes where water runs into, but not out of, the water-storage area. This water does not become part of the available water supply to downstream areas. The hydrologic community has defined "effective drainage areas" to differentiate between the area that would contribute to a designated control point in an average year and the area that would contribute to runoff at the same designated point if all of these terminal lakes, sloughs and so on overflowed in their natural direction towards the same given point (Meid and Mowchenko 1983).

The amount of water lost to this type of nondraining area may be better realized by noting that, in some cases, the gross drainage area is ten times as large as the effective drainage area. Yellow Grass Marsh in southeast Saskatchewan is one of the more striking examples of this type of drainage. In average years, under natural conditions, the marsh would

not contribute to flow in the Souris River basin. It has, however, been drained and contributes flow in almost all years. Its contribution to streamflow in the Souris River is sufficiently large to become part of the computation of natural flow at the international boundary between Saskatchewan and North Dakota.

I have described, up to this point, the typical prairie streams of the Great Plains area. There are, however, some small streams that flow all summer long. The streamflow in these creeks and rivers may be caused by one or more of the following: overflow from large upstream lakes, groundwater sources in or adjacent to the streambed, man-made discharges such as industrial or municipal sewage, or by some other local phenomenon.

There are also some major river systems that pass through this area and a brief discussion of them is in order because they too affect the regional water supply potential. The South Saskatchewan River, in the valley created by glacial runoff, enters Saskatchewan northeast of Medicine Hat, Alberta, and joins the North Saskatchewan River some 30 km west of Nipawin, Saskatchewan. The river is extensively developed in both Alberta and Saskatchewan but, in spite of this, the water still available in this river system is abundant compared to local water resources and any discussion of available supplies for projects adjacent to this stream will probably include the South Saskatchewan River as one potential source.

The North Saskatchewan River enters Saskatchewan east of Edmonton, Alberta, near the boundary city of Lloydminster. The stream's annual yield is not quite as large as the South Saskatchewan River but it is a major source of water and one that has not been extensively developed for consumptive use.

The hydrologic characteristics of both the North and South Saskatchewan rivers are similar (SNBB 1972a). They flow for twelve months a year with water from the Rocky Mountains keeping them alive during the dry summer months. Their low flows are substantially augmented by water released from upstream hydroelectric projects in the fall and winter months. Both rivers typically experience two peak periods, the first occurring in the latter part of April or early May as runoff from the Prairies and Foothills passes downstream. A second larger peak develops in June when snowmelt from mountainous areas of Alberta and Montana enters the rivers.

I will not attempt to analyze such rivers as the Qu'Appelle, Souris, Swift Current, Assiniboine or Battle individually but it is of interest to note that, because each of these rivers is an end product of several

smaller streams, they tend to have smaller peak flows, relative to their drainage areas. The ratio between their effective and gross drainage areas is smaller, and they flow for a much longer time, in some cases for the entire twelve months. Some streams, such as the Assiniboine and Battle rivers are really hybrids. They are partially located on the Plains but some of their headwater areas are in wooded drainage areas where more water is produced on a continual basis and there is a larger percentage of groundwater inflow which keeps the rivers alive during the summer.

Summary

A typical prairie stream will experience streamflow from ten to forty days a year. It will have a gross drainage area that is from five to ten times as large as its effective drainage area and an average yield that is about 1 cm of water based on its effective drainage area. Typically, zero streamflow will be experienced in some years and, in some high-flow years, annual yields might be as high as five times the annual median flow.

GROUNDWATER — QUANTITATIVE CONSIDERATIONS

Groundwater, like surface water, is a renewable resource and forms a valuable part of the water available for use in the prairie region. Unlike surface water, however, it can not be seen and the work needed to verify potential groundwater sources is often costly and time consuming (PPWB 1982). By definition, groundwater means "water below the surface of the land." That includes water in glacial deposits and water in the underlying bedrock formations. Some of this water is usable and some contains sufficient amounts of dissolved material to make it unsuitable for human, agricultural, recreational or industrial use.

The historic geological processes described at the beginning of this paper included reference to the deposition of several layers of porous material. Each one of these layers contains potentially useful water and these water sources may be divided into five categories with the first being the most shallow and the fifth being the deepest (Rey 1983).

1. *Surficial sands and gravels.* These were deposited by the last glaciers that passed over the Prairies. They are relatively shallow, within 50 m of the surface, and usually produce small yields of water suitable for domestic use or for smaller hamlets. There are, however, some large aquifers of this type. The Welby Sand Plains in eastern Saskatchewan is a good example.
2. *Sands and gravels that are part of glacial deposits.* This type of deposit usually is found less than 100 m below the surface. They tend to be more extensive and are capable of producing larger

guaranteed yields. Such aquifers may also be good candidates for aquifer recharge in future years. The Regina and Melville aquifers are good examples of these formations.

3. *Buried valley formations*. The Hatfield and Estevan aquifers are examples of this type of formation. The formations are usually over 100 m deep and were formed in preglacial times. The water in these formations has leached downwards from the surface in more recent years, replacing the more saline waters initially deposited with the formation.

4. *Upper bedrock systems*. The Ravenscrag and Swan River formations are examples of this type of system. They are deposited at lower elevations usually over 200 m deep and the water in these formations is often of questionable quality.

5. *Lower bedrock systems*. The Blairmore and deeper carbonate formations are typical of this type of formation. They are found at depths of over 300 m. While water quantities are more than adequate, water quality is usually not acceptable for normal uses. When used for special purposes, care must be taken to ensure that the saline waters do not pollute other water supplies.

A typical prairie groundwater source may come from any one of the five types listed above. Groundwater is a residual of the water that has filtered down through the soil until it reaches the water table. If this water can be withdrawn at a significant rate it is assumed to be part of an aquifer. Aquifers generally consist of unconsolidated material like sand and gravel or porous fractured rock. They vary both in size and depth below the surface.

Most groundwater sources are too limited to be used for major projects but they do have several advantages over the Plains' surface waters. Groundwater is widespread over the prairie region and can often provide a usable source of water when surface water is not sufficiently near to be practical. Furthermore, the water is usually of a constant chemical quality and temperature from month to month and year to year. The source, because it is under the ground, is not subjected to evaporative losses or surficial pollution but it is more susceptible to groundwater contamination. If the source has been previously proven by test drilling, construction costs will be much lower than for a surface-water reservoir but, in turn, the probable yields will also be lower. If a dependable source has not been identified the search may be extensive and expensive. The pros and cons of using surface water or groundwater for development purposes have been discussed for decades and the long-term answer is to use both to maximize the total water availability.

When the first people roamed these Plains, they used the springs that are dotted throughout the Prairies. They located, and remembered places where groundwater reappeared on the surface and used these for their water supplies. Early settlers followed their lead, using springs and digging wells into the small surficial deposits of sands and gravels. Most of these sources were close to the surface. As they dug deeper in search of water they found that the quality in deeper wells was, in many cases, too saline to be used.

The existing wells on the Canadian Plains were catalogued in the 1930s by Canada Department of Mines. All known wells were surveyed and, based on this information, maps were prepared showing the surficial and bedrock geology and the location and type of wells. The provincial governments have, in recent years, investigated groundwater resources in more detail and have identified examples of all five types of groundwater aquifers listed previously (PPWB 1982). They realize that groundwater is an integral part of the Prairies' water resources and, although aquifers are less abundant than surface-water supplies, they are more widely dispersed.

Some of the high-yield aquifers now being used are located in unconsolidated surficial deposits or in preglacial and bedrock deposits. The bedrock aquifers are usually more extensive, and are typically from one to two orders of magnitude larger than the surficial supplies (Tokarsky 1985, 1986).

Some consideration has been given in recent years to using groundwater to supplement surface water in time of severe drought. For example, Render (1987) has modelled the Assiniboine Delta aquifer and reports that this source could yield continuously from 6,800 to 9,000 cubic decametres per year. During periods of extreme drought this yield could be temporarily increased to as much as 160,000 cubic decametres per year. The long-term effect of this type of "temporary cure" is uncertain but it is known that surface-water droughts are not necessarily connected to periods of below normal groundwater and aquifers are often relatively insensitive to drought. Researchers in Manitoba suggest that most of the major aquifers in Manitoba are drought proof. PFRA has noted that there is a drying effect on surficial aquifers but that the deeper aquifers are apparently not affected in the same way.

Summary

There are many areas where a limited supply of usable groundwater can be obtained. Many of these are now being accessed for both domestic and urban purposes. There are only a few abundant supplies like the Regina and Estevan aquifers.

QUALITY OF SURFACE AND GROUNDWATER SUPPLIES

"Pure water is not found in nature. As it makes its way through the various phases of the hydrologic cycle, water accumulates various substances in suspension, solution and colloidal suspension." That quotation, from the Inquiry on Federal Water Policy (Pearse et al. 1985), describes the problem. Whether the additives are sediment, decomposed organic compounds, metallic elements or pesticides and whether they were caused by nature or by man, these elements make water supplies less acceptable.

Water pollution is defined as "the addition of something to water that changes its natural qualities so that the riparian owner does not get the natural water of the stream transmitted to him" (Wisdom 1956). Pollution, in this context, does not include the deterioration of water supplies from natural cause but it is important to realize that water resources are not naturally pure. An untouched stream of water may still have enough natural additives to make it unsuitable for human use. Obvious examples are saline sloughs. Less obvious examples include springs or wells with enough nitrates to render the water hazardous to new babies, rivers with naturally high levels of arsenic and lakes with algae blooms.

Surface-Water Quality

Typically, the quality of surface water in lakes and reservoirs will vary considerably from natural causes such as rainfall, inflowing water, wind effects and evaporation losses caused by seasonal changes (Childress et al. 1987). The spring runoff period, when snowmelt enters the water channels, is when the quality is the best. Snowmelt carries fewer contaminants per unit volume of flow than runoff in summer months. As the flow decreases, the concentrations of various chemicals increase. In the summer, standing water is concentrated by evaporative losses. Concentration by freezing also occurs in the winter.

One of the more common parameters to assess water quality has been total dissolved solids (TDS). This measures the total concentration of all dissolved substances in the water being sampled. The main elements are calcium, magnesium, sodium and potassium cations and bicarbonate, carbonate, sulphate and chloride anions. The conclusions from a recent study (Hydroqual Consultants Inc. 1986) on the waters of the North and South Saskatchewan river basins indicate that the average TDS in both rivers is from 200 to 300 mg/L and that the TDS is higher in the winter and lower in the summer. The results suggest that the present level of

salinity in the North and South Saskatchewan rivers is reasonably low and that there are no major fluctuations in TDS throughout the basin.

In smaller streams on the Prairies, TDS levels are usually higher. On Chaplin Lake, in Saskatchewan, readings as high as 100,000 TDS were recorded before a sodium sulphate extraction plant was built. This TDS level is not representative of all lakes on the Prairies but it gives some indication of what can happen when annual runoff from a prairie environment is ponded in a depressed area with no natural outlet. The white edge outlining many of our prairie sloughs bears mute testimony to their high level of salinity. TDS levels of over 1,000 are common on several of the larger prairie lakes.

The quality of surface water, based on monitoring programs, can be broken down into three types (Allison 1978): natural chemicals — major ions contributing to salinity, minor elements and nutrients; biological factors — plants, algae, macrophytes and bacteria (Waite 1982); and anthropogenic factors — artificially produced chemicals such as pesticides.

Traditional monitoring methods have been used to measure TDS, dissolved oxygen, nitrogen, phosphorus and the major ions usually found in water (Water Quality Branch 1985). To this list have been added several of the compounds made by man and used on the land. Some insecticides and herbicides and industrial chemicals including PCBs, are regularly monitored and the results are reported to concerned agencies (Allison 1980). At the eleven interprovincial monitoring sites maintained for the Prairie Provinces Water Board, for example, a total of ninety-eight parameters (PPWB 1990) have been identified and these are routinely monitored on a monthly basis by the Water Quality Branch of Environment Canada.

Groundwater Quality

The chemical composition of groundwater supplies varies somewhat from surface-water supplies. Because the water has filtered through soil and/or rock as it travels towards the aquifer, groundwater is almost free from any suspended sediments. Similarly, because it usually does not contain organic matter or oxygen, bacterial activity is minimal. Typically, however, groundwater will pick up carbon dioxide near the surface and this compound dissolves minerals such as calcium, magnesium, iron and arsenic. The result, particularly in deeper aquifers, is a hard water that may not be suitable for use.

The provincial agencies in charge of groundwater allocation and investigation in the three prairie provinces have established what they refer to as the "base of groundwater exploration" (Tokarsky 1985, 1986).

Groundwater below this level is considered to be too highly mineralized, or saline, to be used for domestic or stockwatering purposes. That line, generally speaking, is some 300 feet below the surface in Saskatchewan and water below that level is assumed to contain more than 4,000 ppm of total dissolved solids.

The basic quality of groundwater sources remains constant throughout the year and the source temperature is also constant and cool. In some instances there are hot mineralized springs from deep volcanic sources that find their way to the surface and it is known that thermal wells can be found in deeper formations. At these levels the water is not usable for most consumptive purposes but may used for heating, electrical generation, chemical extraction and other such uses.

Groundwater sources usually require less treatment than surface waters and are often preferred because they have a constant colder temperature and a consistent quality. Taste and odour problems are not usually associated with groundwater supplies but their higher mineralized content makes them a questionable source in many instances. Also, the iron and iron bacteria sulphides in some groundwater sources may make the water unacceptable. The traditional treatment methods used to remove dissolved minerals from water are expensive and their use is not widespread in the Plains basin.

Summary

Surface water in the Plains region will typically have a higher level of TDS, will be hard and high in nutrients that promote algae growth. Groundwater from wells of less than 300 feet in depth will generally be drinkable but will be hard in most cases. Water drawn from deeper aquifers will, for the most part, be saline and unfit for human consumption. Because of the possibility of additional contaminants in groundwater all sources should be tested before being approved for household use.

RELATIONSHIP OF WATER TO THE ENVIRONMENT

Any discussion of the characteristics of water supplies in the Great Plains of Canada would not be complete without some comment on the environment surrounding these supplies (McKay et al. 1989). Water is a basic necessity of life for animals and plants that live on the Plains. The areas close to water supplies, both streams and lakes, provided cover for nesting purposes, protection against the hot and hostile climate and the water kept the brush and trees in these areas alive and growing. When water was not available the wildlife, like the nomadic people they lived with, migrated to where water supplies were adequate.

In periods of drought there were fish kills as the supplies became unable to support the existing fish population. Similar hardships affected both the animals and birds using this resource. The periodic flooding in prairie streams such as the Qu'Appelle River would kill the growth adjacent to the rivers and, in doing so, would destroy the wildlife nesting and protective cover. Successive droughts would give this growth an opportunity to return again to cover and protect the stream's edge and the animals who used it.

This natural pattern was disturbed when the settlers reached the Prairies. Brush cover was replaced by crops and the stream's natural course was dammed and diverted. Effluent from municipal, agricultural, industrial and recreation practices began to change the character of these streams and raised the inevitable questions as to what is being done, both to the rivers and to the wildlife population that relied upon these rivers for their existence. The residuals from crop spraying and fertilization find their way into the prairie lakes and all life chains and the people living on the Prairies must now face the consequences of imposing civilization on a somewhat fragile water-based environment. Such things as the effect of thermal pollution below power plants and the release of sewage into waterways that do not have enough assimilative capacity to cleanse and purify that effluent must become part of the chain of considerations faced in future years.

CONCLUSION

The water resource base of the Canadian Prairies has been defined in a brief way in this paper. It is a limited description of a limited resource. Captain Palliser referred to the Prairies as a desert and drew his now famous Palliser Triangle. Maybe the entire prairie area should have been left as some large natural park with no settlement allowed, but such speculation is useless. We are here and we are not going to leave.

There are many positive things to be said about living here on the Prairies and drinking this water. The environmental concerns are of the type that can be controlled or reversed before the existing environment is destroyed. Survival of this environment is both a trust and a responsibility and vigilance in the form of continuing monitoring of the surrounding environment is the only way that the trust can be adequately maintained.

This is the real challenge. What can be done with these limited water resources? How can they be used effectively without depleting them past the point of no return as civilization continues to live and grow on the Canadian Plains?

BIBLIOGRAPHY

Allison, E.W. 1978. A long term first order minimum water quality network for the prairie provinces. Prairie Provinces Water Board, Regina.

Allison, E.W. 1980. A summary of Prairie Provinces Water Board water quality activities. Prairie Provinces Water Board, Regina.

Childress, C.J.O., T.H. Chaney, D. Myers, J.M. Norris and J. Hren. 1987. Water quality data-collection activities in Colorado and Ohio. Phase 2 — Evaluation of 1984 field and laboratory quality-assurance practices. Open-File Report 87-33. U.S.G.S., Columbus, Ohio.

Environment Canada. 1988. Historical streamflow summary. EN 36-418/1988-4. Supply and Services Canada, Ottawa.

Godwin, R.B., B.L. Foxworthy and V.A. Vladimirov. 1990. Guidelines for water resource assessments of river basins. IHP-III Project 9.2. Unesco Technical Documents in Hydrology, Unesco, Paris, France.

Hydroqual Consultants Inc. 1986. Total dissolved solids trends in the Saskatchewan River basin. Water Quality Branch, Environment Canada, Regina.

McKay, G.A., R.B. Godwin and J. Maybank. 1989. Drought and hydrological drought research in Canada. CWRA Journal 14 (3).

Meid, P.O. and M. Mowchenko. 1983. The determination of gross and effective drainage areas in the Canadian Prairies. Hydrology Division Report No. 104. PFRA, Agriculture Canada, Regina.

Pearse, P.H., F. Bertrand and J.W. MacLaren. 1985. Currents of change: Inquiry on federal water policy. Environment Canada, Ottawa.

PPWB. 1982. Water demand study: Historical and current water uses in the Saskatchewan River basin. Main report. Prairie Provinces Water Board, Regina.

PPWB. 1990. Annual report for the year ending March 31, 1989. Prairie Provinces Water Board, Regina.

Render, F.W. 1987. Water supply capacity of the Assiniboine Delta aquifer. CWRA annual conference. Unpublished.

Rey, T.W. 1983. Concerns associated with increased utilization of ground water. *In* Proceedings, prairie hydrology technical session at CWRA Meeting. Water Studies Institute, Saskatoon.

SNBB. 1972a. Water supply for the Saskatchewan-Nelson basin. Main report. Prairie Provinces Water Board, Regina.

SNBB. 1972b. Study background. Appendix number one to the main report. Prairie Provinces Water Board, Regina.

Storer, John. 1989. Geological history of Saskatchewan. Saskatchewan Museum of Natural History, Regina.

Tokarsky, O. 1985. Hydrogeologic profile: Alberta-Saskatchewan boundary. Prairie Provinces Water Board, Regina.

Tokarsky, O. 1986. Hydrogeologic profile: Saskatchewan-Manitoba boundary. Prairie Provinces Water Board, Regina.

Waite, D.T. 1982. Biological monitoring of industrial and municipal wastes: The Saskatchewan experience. Symposium No. 8. Water Studies Institute, Saskatoon.

Water Quality Branch. 1985. The business of the Water Quality Branch. Inland Waters Directorate, Environment Canada, Ottawa.

Winter, T.C. 1989. Hydrologic studies of wetlands in the northern Prairies. *In* Northern prairie wetlands, 16-54. Iowa State University, Ames, Iowa.

Wisdom, J.O. 1956. Foundation of inference in natural science. Methuen, London, England.

Rapporteur's Report

G.A. Fuller

Bruce Godwin gave an interesting and thought-provoking discussion on the characteristics of the Great Plains water supplies. As he stated, they "are a function of the land from which they originate." As a result, our water supplies on the Plains fluctuate between drought and flood conditions.

This discussion on the characteristics of our water supplies and sources focusses primarily on Bruce's concluding remarks. He indicated that the challenge before us was the efficient utilization of our limited water resources without depleting them past the point of no return. In facing future challenges, we cannot assume that the limited historic water-supply data we have will be representative of the future due to changing climatic conditions (global warming and depletion of the ozone layer). The increased evaporation due to these changes is expected to result in a reduction of future surface runoff on the Plains. This will result in less than the 1 cm of annual runoff we now receive based on Bruce's estimated effective to gross drainage area ratio of 1 to 10.

There can be no doubt that the Plain's water supplies have unique

characteristics. Consequently, we must develop our own unique solution to our water-supply problems in order to make the best use of our supplies. There are many examples of solutions that have contributed to the wise use of our water supplies. One example is a small community that fills a reservoir with readily available saline groundwater, allowing it to freeze. (Our winter climate is well suited for this purpose.) The concentrated saline solution is drained from the reservoir and used for commercial sulfate production. After the ice melts in the reservoir during the spring, it is used for domestic purposes.

Another exemplary water-supply solution was found by a community with an insufficient quantity of good quality surface water. They carefully mixed the surface water with controlled amounts of readily available poor quality groundwater. In this way they are able to satisfy both their water-quantity and water-quality requirements. Due to the availability of considerable amounts of poor quality groundwater on the Plains, we need to put more emphasis on making use of this resource. One possibility is developing low-cost methods of treating this saline water for domestic use on farms and villages.

To assist in efficient utilization of all components of our water supplies, more research is required on all phases of the hydraulic cycle that occur in our watersheds, especially watersheds of less than 10 square kilometres. In studying these basins all aspects of the hydraulic cycle should be considered. The concentration on making improvements in efficiencies on one portion of the watershed may reduce efficiencies in another portion.

Discussions on water supply are somewhat discouraging in that we always come up with more questions than answers. However, there are some encouraging signs. It appears that we do learn from the extreme conditions we are faced with on the Plains. For example, the drought we experienced in the 1930s was probably not as severe as the drought we experienced in the 1980s. However, the recent drought was not as devastating to our farm conditions, for example, water supplies and soil drifting. This is due, at least to some extent, to the successful government conservation programs initiated after the earlier drought by, for example, PFRA in Canada and the U.S. Army Corp of Engineers.

The main theme that keeps reoccurring in discussions regarding future water supplies is that additional research and development is required on utilizing our water supplies. This will assist us in making the best use of our limited, and somewhat unique, water supplies here on the Great Plains.

Technologies and Strategies Used to Develop and Access Water Supplies on the Great Plains: Water-Quality Considerations

P. Tones and R.S. Pentland

On the Canadian Prairies, some of the most widespread water-quality problems are nutrient enrichment, inadequate dissolved oxygen, bacterial contamination and high salt content. Issues related to toxicity may be important, but they tend to be restricted to specific locations. Many of the strategies currently used to access water supplies encounter poor quality water and some strategies exacerbate existing problems.

SMALL RURAL SURFACE-WATER RESERVOIRS

Rural water supplies are particularly known for their poor quality. Small surface-water reservoirs such as "dugouts" often have high levels of available nutrients resulting in intense biological activity, especially phytoplankton growth. When the level of chlorophyll *a*, a common photosynthetic pigment, reaches 0.05 mg/L, the condition is referred to as a "bloom." On the Canadian Prairies, blooms primarily consist of cyanobacteria (blue-green algae) and green algae.

Hans Peterson (1989) of the Saskatchewan Research Council summarized the impact of blooms on water supplies. The water may be unsuitable for consumption due to: toxin production by cyanobacteria; turbidity increase; taste and odour increase; manganese increase; pH increase; and wide fluctuations in ammonium and oxygen levels.

In addition to the direct effect of blooms, water from small reservoirs may be unsuitable for consumption because of pesticide residues, turbidity due to soils washed in from the surrounding tilled lands, and growth of rooted aquatic plants. Domestic treatment of poor quality water from the dugout is made difficult because of: filter clogging; ineffective filtering of small green algae; and ineffective chlorination of water containing green algae. Domestic treatment systems may also introduce by-products such as organochlorines formed during water chlorination and bacteria from overloaded systems.

Cyanobacteria can produce toxic substances — primarily hepatotoxins and neurotoxins. As little as 1.3 L of bloom water can cause death in a calf (Carmichael and Schwartz 1984). In a 1989 case of cattle death in Radville, Saskatchewan (Peterson 1963), eleven cattle died within minutes of drinking water containing a bloom of the cyanobacterium *Anabaena*. The farmer treated the reservoir with copper sulphate, the most commonly used algicide. The following day, there were no algal cells left although the water had a bluish colour. The farmer allowed the cattle to drink from the reservoir and five more cattle died. Several cyanobacterial toxins are extremely stable and will remain in the water for several days after the algal cells have died. Liver damage has been demonstrated in a human population that was supplied water containing the cyanobacterium *Microcystis* (Falconer et al. 1983).

Any type of control of algal populations will cause water-quality deterioration, if the algae reach bloom concentrations. The most common treatment for cyanobacteria has been copper sulphate. This treatment, at high doses, will kill zooplankton. The death of the cyanobacterial cells also releases nutrients to the water. Nitrogen concentrations often drop to extremely low levels in prairie reservoirs over the summer limiting the growth of green algae. Thus, the sudden increase in nutrients and the loss of biological control from zooplankton grazing often result in a secondary bloom of green algae. Peterson and Swanson (1988) found that blooms of green algae typically occur in prairie dugouts with a history of copper treatments at high doses. Species of small green algae commonly found in the secondary bloom cause the greatest technical problems because they pass through commercially available domestic filtration equipment. The result is tap water with the colour, but not the taste, of lime juice. These copper-tolerant green algae are not controlled by copper sulphate applications.

The long-term goal is the prevention, rather than the treatment, of phytoplankton blooms. This goal is difficult to achieve. Cyanobacteria are relatively unpalatable to zooplankton. Some species of cyanobacteria such as *Aphanizomenon* and *Anabaena* fix nitrogen from the atmosphere; therefore they are independent of the dissolved nitrogen supply. Watershed-management strategies that reduce nitrogen inputs to reservoirs are not likely to be effective in controlling these species of cyanobacteria.

A range of techniques are currently available to improve water quality. The best overall strategy is often a combination of these, used before a serious problem develops. Small reservoir management practices that may improve water quality include: pesticide application;

manipulation of nitrogen to phosphorus ratios; lime [$CaCO_3$ or $Ca(OH)_2$] application; introduction of duckweed (*Lemna* sp.); black plastic pond covers; aeration; and erosion protection (for example, grassed waterways, buffer strips). The two current pesticides allowed in Saskatchewan are copper sulphate for algal control, and diquat (common brand name, Reglone A) for aquatic weed control.

Algal growth can be slowed by using shade to reduce photosynthesis. This can be done naturally by introducing a floating-leaf plant such as duckweed or artificially by adding a synthetic pond cover such as black plastic. These techniques are limited to small protected reservoirs. Continuous aeration is necessary in covered dugouts containing large quantities of organics.

The addition of lime [$CaCO_3$ or $Ca(OH)_2$] to a hard-water, hypereutrophic lake in Alberta resulted in a decrease in chlorophyll *a* concentrations within fourteen days of treatment (Prepas et al. 1990). The short-term reduction may have been due to the precipitation of growth-limiting nutrients other than phosphorus, such as iron. Although chlorophyll *a* returned to pretreatment concentrations within thirty-five days, the treatment caused a longer term reduction in open-water concentrations of total phosphorus, likely due to changes in the phosphorus-binding capacity of the bottom sediments. Under-ice concentrations of total phosphorus were less than half the pretreatment values and during the following summer, the average concentration of total phosphorus decreased by 30 percent. The lime treatments appear to be nontoxic to invertebrates and vertebrates.

Over the past three years, the Zoology Department of the University of Alberta and Alberta Agriculture have been working on a joint lime-application project which has moved quickly from the research stage in 1988 to on-farm demonstrations in 1989 and to provincewide acceptance (Buchanan 1991). In 1990, over 700 farm dugouts across Alberta were treated. The treatment has not yet been proven in Saskatchewan and Manitoba.

The alternative strategy to the current problem-specific approach is an integrated strategy that views water supply as a completely integrated system from the watershed to the small reservoir, through the treatment system and ultimately to the consumer (Saskatchewan Research Council et al. 1990). This strategy places greater emphasis on preventative technologies and on treatment technologies used in combination.

GROUNDWATER SUPPLIES

The poor quality of groundwater supplies is often due to imbalances and excesses of ions. The difficulty in obtaining fresh drinking water on

the Great Plains can be illustrated by comparing the Saskatchewan drinking water quality objectives (Saskatchewan Environment and Public Safety 1991a) to the Canadian drinking water quality guidelines (Health and Welfare Canada 1989). For example, the Canadian and Saskatchewan objectives for total dissolved solids (TDS) are 500 mg/L and 1500 mg/L, respectively. Many groundwater and surface water-well supplies would not be able to meet the federal 500 mg/L guideline (Figure 1). Over one-third of Saskatchewan groundwater supplies reported TDS values exceeding the province's 1500 mg/L maximum desirable objective (Saskatchewan Environment and Public Safety 1991a). Objectives for variables such as alkalinity, hardness, magnesium, sodium and total dissolved solids are specific to Saskatchewan and do not follow the Canadian guidelines.

Groundwater supplies may also contain iron and manganese at levels that discolour water and clog pipes. Areas known to have iron and manganese problems exist in all three prairie provinces and the northern prairie states. Bacterial growth, often associated with iron and manganese, will form a bioslime around the well. This slime isolates bacteria to such an extent that shock treatments such as disinfection or acidization cannot reach the more protected organisms (Cullimore 1989).

A blended chemical heat-treatment strategy developed at the University of Regina (Mansuy and Cullimore 1989) applies maximal shock to the micro-organisms by applying a high dosage of disinfectant, an elevation in temperature, and a shift in pH to either very alkaline or acid, followed by surges containing dispersants which remove the bioslime after it has detached from the wall of the well. This technique has been used on relief wells and municipal water-supply wells in the United States. Of the thirty-eight wells treated by this process thirty-six have returned to acceptable capacities and water standards.

The quality of groundwater supplies can be improved on an individual well basis. The technology for shock treatment of bioslime is one example of well remediation. Another example is "well-head protection" which delineates zones around existing wells or well fields. Activities within these zones are restricted to prevent well contamination. This presumably allows sufficient time for detection and cleanup of contamination originating outside the zone before production wells are affected.

The scope of groundwater protection can be broadened, however, from individual wells to technologies and strategies used on a regional basis. The Regina Groundwater Project is one example of water-supply protection in a wider scope.

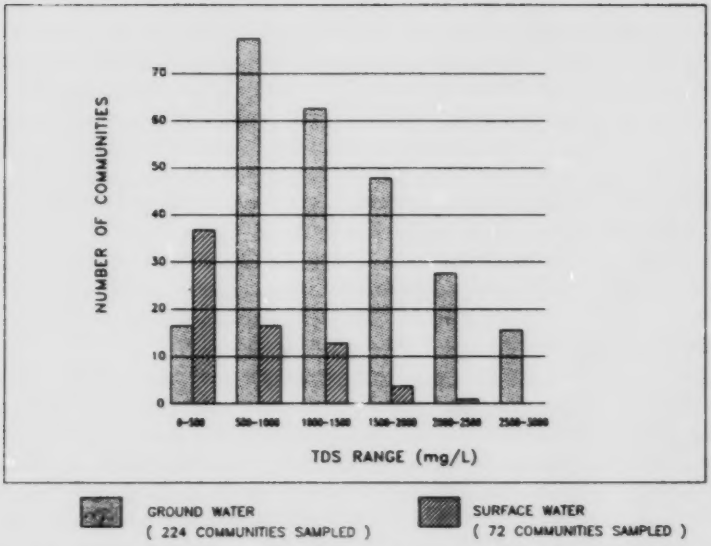

Figure 1. Comparison of total dissolved solids values, ground and surface water supplies, 1988-1989.
Guideline for Canadian drinking water quality TDS = 500 mg/L; Saskatchewan municipal drinking water quality objective TDS = 1500 mg/L.

Source: Saskatchewan Environment and Public Safety, 1991b.

Aquifers in the Regina, Saskatchewan area provide about 35 percent of the drinking water of the city of Regina and up to 100 percent of the drinking water of surrounding communities. Groundwater from the aquifers is used extensively by local industry and agriculture. The aquifer systems in the Regina area are some of the most complicated, yet heavily developed, networks in North America. The Regina aquifer system consists of five main aquifers as well as local isolated aquifers occurring at a range of depths. Groundwater data indicate that one of the aquifers, Condie aquifer, has become partially contaminated due to human activity in the Regina area (Maathuis and van der Kamp 1988). Concern for groundwater contamination prompted the Water Quality Branch of Saskatchewan Environment and Public Safety to initiate the Regina Groundwater Project.

The Regina Groundwater Project includes studies on the

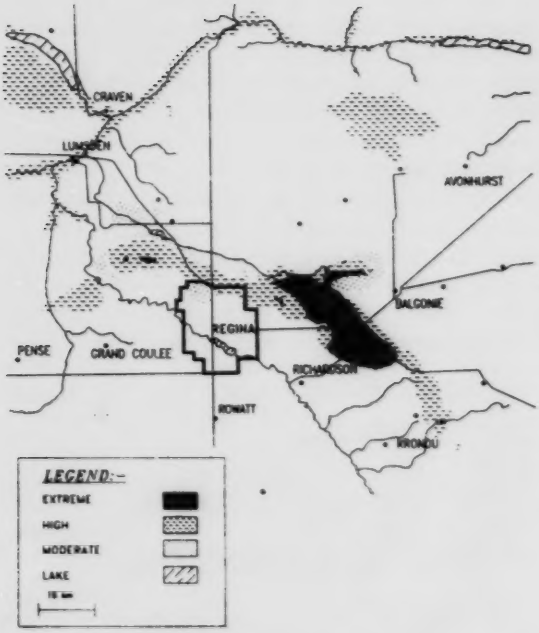

Figure 2: Groundwater sensitivity map of Regina area.

Source: Saskmont 1990.

hydrogeology of the aquifer systems (Maathuis and van der Kamp 1988), groundwater quality (Golder 1987), contaminants (Saskatchewan Environment and Public Safety 1989), and a design and installation protocol for sampling wells (Stanley Associates 1989). A key component of the project is the monitoring program. The monitoring strategy is to have regional monitors including "uncontaminated" (control) monitors and "representative" monitors that are representative of existing groundwater quality in the region (ESSA 1991). This set of regional monitors would be selected randomly and provide the overall regional picture. The regional monitors would be supplemented by "early warning" monitors located upstream and downstream of sites of potential contamination. The monitoring strategy is a key component of the project, but it is reactive. It detects contamination after it has occurred although early enough to remediate the contamination.

The proactive component of groundwater protection includes sensitivity mapping to identify lands over the aquifer that are more susceptible to contamination than others (Saskmont 1990). In the Regina area, overburden thicknesses vary significantly. There are outcrops of aquifer sands at the surface that are not protected by a clay or till overburden. Such an area exists about 20 km east of downtown Regina in the Pilot Butte-White City area (Figure 2).

Sensitivity mapping is only proactive if it is coupled with land-use guidelines and appropriate control mechanisms for aquifer protection. The direct approach would consist of legislation that is specific to aquifer management and protection; the indirect approach is problem-specific and would use guidelines and existing legislation. The direct approach would provide the strongest long-term protection (Saskmont 1990).

LARGE RIVER AND RESERVOIR SUPPLIES

Municipal and Industrial Impacts

Large rivers originating in the mountains provide the most reliable source of high-quality water in the Canadian Prairies. This water supply has been exploited since the Prairies have been settled. Major cities and industries have located near the rivers with subsequent degradation of water quality.

The most pervasive, well-documented impact on water quality and the aquatic biota has been the increase in nutrients. Total phosphorus and chlorophyll *a* (from both free-floating and attached algae) concentrations in the North Saskatchewan River in the vicinity of Edmonton are considerably higher downstream of the city than upstream (Anderson et al. 1986). The largest source of phosphorus is the Gold Bar Wastewater Treatment Plant. Zoobenthic organisms were used to identify major zones of impact. Municipal discharges, including storm and combined sewers, were largely responsible for the impacted zones in the North Saskatchewan River at Edmonton (Anderson 1986).

Similar impacts have been reported for the South Saskatchewan River and its tributaries. Substantial increases in macrophytes (aquatic weeds) occur on the Bow River below Calgary (Charlton et al. 1986). In spite of tertiary treatment of Calgary sewage, the plant biomass has not significantly decreased at many locations, due possibly to phosphorus deposits in the sediments (Sosiak 1990). Studies on the Bow River have shown the importance of current velocity on the scouring of macrophyte biomass and the scouring of phosphorus-rich sediments (Chambers et al. 1991). Nutrient levels in the Red Deer River are significantly increased by treated-sewage discharges at Red Deer, Drumheller and Jenner. A

notable increase in invertebrate numbers and biomass was observed downstream of the city of Red Deer as a result of the enrichment by treated-sewage discharges (Cross 1991). Increases in aquatic macrophytes occur on the South Saskatchewan River in reaches receiving increased nutrient loading as a result of sewage inputs such as the reach below Saskatoon (Tones et al. 1980).

Rivers originating in the Western Interior Physiographic Region, such as the Red, Souris, Qu'Appelle and Assiniboine rivers, have a flow that is extremely variable and water that is eutrophic or hypereutrophic. A recent planning workshop on the Red-Assiniboine river basin addressed increased biological growth in surface waters as an important issue. The Souris River which flows through Saskatchewan, North Dakota, and Manitoba is an interesting example because of the impact of managed wetlands. Both nitrogen and phosphorus increase substantially within the North Dakota portion of the Souris River. Total phosphorus loading in the river as the water enters Manitoba tends to be three times that recorded as it leaves Saskatchewan (Environment Canada 1989, 1991). Treated municipal sewage is discharged to the river throughout its length, but major additional sources of nutrients are the national wildlife refuges located in North Dakota, particularly the J. Clark Salyer National Wildlife Refuge near the Manitoba border. All across the northern Great Plains, one of the most well-documented, pervasive impacts on surface-water supplies is the impact of excessive nutrients on the alteration of water quality and the aquatic communities.

The South Saskatchewan River Basin Study (1991) final report has recently addressed this fundamental problem. The report set out basin-management strategies for long-term planning. It presented scenarios of the water quality below Saskatoon with and without a new commitment to water-quality protection. If the historic patterns of development continued for another thirty years, water quality downstream of Saskatoon would deteriorate as a result of increased effluent volume. Summer phosphorus levels would increase 35 percent. If the city of Saskatoon upgraded its sewage-treatment system to include removal of phosphorus, a 50 percent reduction in the concentration of phosphorus in the river downstream of the city was predicted despite the increase in effluent volume. The protection of our existing water supplies will depend on a firm commitment to a long-term basin strategy. The reduction of nutrient-related impacts on the Saskatchewan River system will not be easy, as comprehensive, long-term research on the Bow River has shown.

Increases in coliform bacteria below municipal discharges of treated

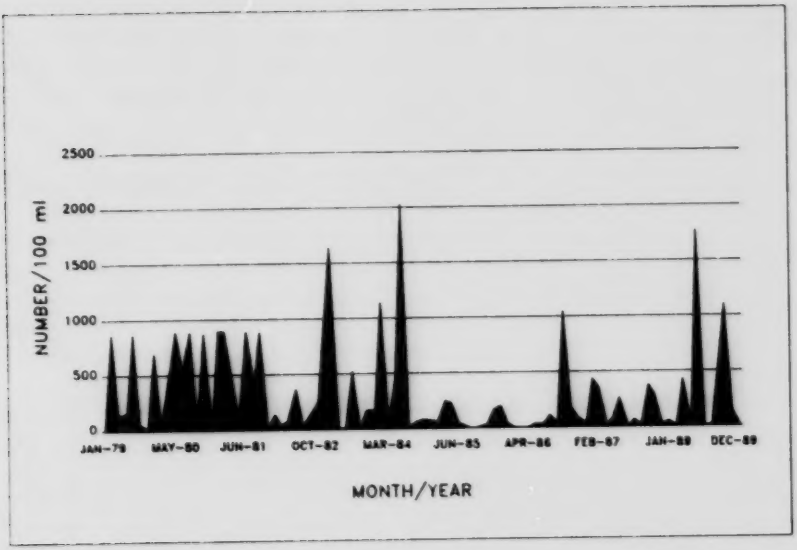

Figure 3. Fecal coliform densities, South Saskatchewan River at Clarkboro Ferry (west side).

Source: Saskatchewan Environment and Public Safety, 1991b.

sewage and stormwater are also well documented. Coliform bacteria have been detected at Clarkboro Ferry on the South Saskatchewan River downstream of Saskatoon (Figure 3). Many samples exceeded the water-quality objective for fecal coliform bacteria of 200 counts/100 ml (Saskatchewan Environment and Public Safety 1991b). Fecal coliform bacterial levels indicated a deterioration in water quality in the North Saskatchewan River below the city of Prince Albert (Saskatchewan Environment 1984). Total and fecal coliform counts in the Bow River (Sosiak 1990) exceeded the water-quality objectives for direct contact recreation and irrigation. There has been a gradual increase in counts over time. Bacterial populations in the Red Deer River frequently exceeded objectives below the cities of Red Deer, Drumheller and Jenner (Cross 1991). Again, there is substantial documentation of the impairment of water quality from municipal discharges.

Although toxicity can result from ammonia discharges from sewage-treatment plants and from industrial and mining sources, toxic impacts are not commonly reported. Benthic surveys of the North Saskatchewan River at Edmonton, which has a large industrial base, could not detect the impacts of industrial discharges although impacts may be masked by the dominant municipal impacts. There does not appear to be a measurable toxic effect in the North Saskatchewan River, although toxic contamination on industrial sites can reach the river via contamination of groundwater and direct effluent discharge. Although locating industries adjacent to rivers originally minimized water-supply costs, the current and potential problems of site remediation to protect river water from contamination are substantial as older industries try to achieve the environmental expectations of the 1990s.

The use of alternate technologies to stretch existing water supplies is occurring in the industrial sector. Of the seventeen effluent permits issued for industrial operations in Saskatchewan in 1989, seven of these were for zero-discharge operations. This is an encouraging trend. The nitrogen fertilizer industry, which can exacerbate river eutrophication by discharging nitrogen in wastewater, is an example of this trend. Three existing plants, at Medicine Hat, Redwater and Fort Saskatchewan, are permitted to discharge from 127 to 210 tonnes of ammonia nitrogen to the North or South Saskatchewan rivers annually. A fourth existing plant employs effluent irrigation. The newest plant under construction initially considered discharging treated wastewater to the Moose Jaw River on the Qu'Appelle River system. However, to avoid adding an additional nitrogen load to this river system, in which plant growth is at least partially limited by nitrogen, the design was changed to zero effluent discharge (Beak Associates 1990). The design is feasible because of extensive internal recycling of water and evaporation of final effluent. Zero discharge is not always technically or economically feasible, but this option is now being given serious consideration by industry.

WATER-SUPPLY PROJECT IMPACTS

Major water-supply projects such as reservoirs, interbasin transfers, canals and pipelines have been envisioned on a water quantity basis. The water quality implications of these decisions are now becoming better known, although not always understood.

One of the greatest advantages of Lake Diefenbaker, a major reservoir on the South Saskatchewan River, has been the presence of a high-quality supply that does not have the substantial blue-green blooms that characterize most of the hypereutrophic waters of central and southern Saskatchewan. When comparing data on the input to Lake Diefenbaker

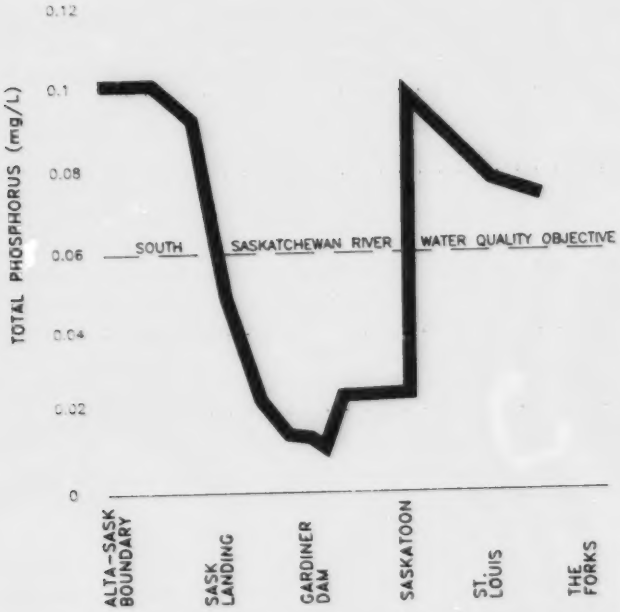

Figure 4. Summer phosphorus levels in the South Saskatchewan River, Saskatchewan.

Source: South Saskatchewan River Basin Study, 1991.

of phosphorus, a nutrient limiting algal growth in this reservoir, to data on the output of phosphorus, Weagle and Crosley (1989) concluded that the lake acts as a phosphorus sink for the South Saskatchewan River basin (Figure 4). There is little or no regeneration of phosphorus from the sediments at present. Over the period from 1985 to 1988, the average accumulation of phosphorus in the sediments was 945 tonnes per year. Further examination showed that 45 percent to 55 percent of the accumulated phosphorus was bioavailable. This led Weagle and Crosley (1989) to conclude that any change in the oxygen regime in the lake would cause a significant deterioration in trophic status. Oxygen depletion over extended periods would cause the release of a significant amount of settled phosphorus from the sediments; the most likely immediate effect would be an upsurge in bloom-forming algae. If nutrient concentrations are allowed to increase in the main portion of the

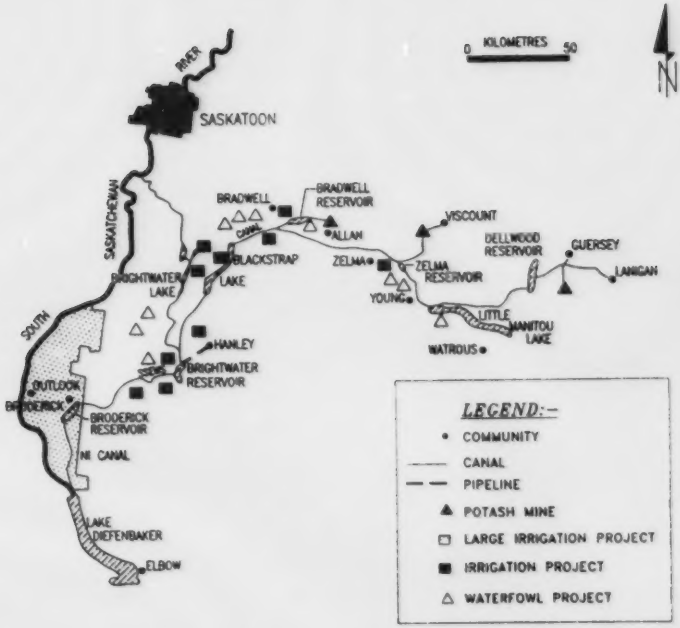

Figure 5. Saskatoon South East Water Supply system.

Source: South Saskatchewan River Basin Study, 1991.

reservoir, algae and aquatic weeds would cause problems for most uses, reducing the reservoir's value to southern Saskatchewan. It is imperative that the development strategy for Lake Diefenbaker does not alter the oxygen regime of the lake.

Codette Lake, a reservoir on the Saskatchewan River downstream of Lake Diefenbaker, exhibits severe oxygen depletion in August. Water-quality objectives for dissolved oxygen are not met. Although Saskatchewan Environment has documented the problem, the underlying cause is not readily apparent (K.P. Lauten, pers. comm.). The city of Melfort will become an important water user as a pipeline is constructed by Sask Water from Codette Lake to Melfort and other towns in the vicinity.

The Saskatoon South East Water Supply (SSEWS) system is largely fed from water pumped from the downstream end of Lake Diefenbaker. The

SSEWS system consists of a series of pump stations, canals and reservoirs. It begins at Lake Diefenbaker and ends near Lanigan, 150 km away. The system delivers water to towns, potash mines, irrigation projects and waterfowl projects (Figure 5). The system includes six reservoirs which are in a downstream sequence — Broderick, Brightwater, Blackstrap, Bradwell, Zelma and Dellwood.

Water quality is an issue within the SSEWS system. Nutrient levels increase with distance from the source. At Blackstrap Lake nutrients produce algal blooms and weed growth that inhibit recreation. From Blackstrap Lake downstream, the reservoirs have substantive algal populations and frequent blooms of cyanobacteria (HydroQual and M.R.2. 1990). High levels of chlorophyll *a* have been measured in Bradwell, Zelma and Dellwood reservoirs. The deterioration in water quality has not, however, prevented stocking of sport-fish populations in the reservoir.

Due to high evaporation rates and inflows of highly saline groundwater, the salinity of the water increases with the distance from Lake Diefenbaker. Concentrations of salt in Bradwell and Zelma reservoirs has increased to the point that irrigation of some crops is not possible (South Saskatchewan River Basin Study 1991).

In 1986, the governments of Canada and Saskatchewan signed a large irrigation-based economic development agreement which has led to considerable development around Lake Diefenbaker. When fully developed the Lucky Lake and Riverhurst pressurized pipeline irrigation projects will serve more than 20,000 hectares of irrigated land plus associated projects (South Saskatchewan River Basin Study 1991). Outside of the irrigation season, the pumping facilities of the recently completed Lucky Lake project deliver about 7,000 dam^3 of water to a nearby waterfowl project. Pipeline projects such as this, although expensive, overcome the water-quality problem of canal systems such as the SSEWS system.

In conclusion, one of the best ways to stretch the existing water supplies of the Great Plains is to improve their water quality, making the existing water available for a wider range of uses. At the very least, protection of water quality is essential to protect current uses.

BIBLIOGRAPHY

Anderson, A.M. 1986. North Saskatchewan River: characterization of water quality in the vicinity of Edmonton (1982-1983). Part 2. Zoobenthic surveys of spring, summer and fall 1982. Water Quality Control Branch, Alberta Environment, Edmonton.

Anderson, R.S., A.M. Anderson, A.M. Akena, J.S. Livingstone, A. Masuda, P.A. Mitchell, T.B. Reynoldson, D.O. Trew and M. Vukadinovic. 1986. North Saskatchewan River: characterization (1982-1983). Part 1. Introduction, water chemistry, chlorophyll, bacteriology. Water Quality Control Branch, Alberta Environment, Edmonton.

Beak Associates Consulting Ltd. 1990. Saferco Products Inc. nitrogen fertilizer plant at Belle Plaine, Saskatchewan, environmental impact statement. Prepared for Saskferco Products Inc., Regina.

Buchanan, R. 1991. Liming improves dugout water quality. Prairie Water News 1(1): 8.

Carmichael, W.W. and L.D. Schwartz. 1984. Preventing livestock deaths from blue-green algae poisoning. Farmers Bulletin No. 2275. U.S. Dept. Agriculture.

Chambers, P.A., E.E. Prepas, H.R. Hamilton and M.L. Bothwell. 1991. Current velocity and its effects on aquatic macrophytes in flowing waters. Ecological Applications 1(3): 249-57.

Charlton, S.E.D., H.R. Hamilton and P.M. Cross. 1986. The limnological characteristics of the Bow, Oldman and South Saskatchewan rivers (1979-1982). Part 2. The primary producers. Water Quality Control Branch, Alberta Environment, Edmonton.

Cross, P.M. 1991. An overview of water quality in the Red Deer River basin (1983-1984). Environmental Quality Monitoring Branch, Alberta Environment, Edmonton.

Cullimore, D.R. 1989. Observations on the bacterial populations recovered from water wells subjected to disinfection. Can. Water Resources J. 14(4): 35-41.

Environment Canada. 1989. Rafferty-Alameda project: Technical report. Vol. 1. Initial environmental evaluation. Conservation and Protection, Environment Canada, Regina.

Environment Canada. 1991. Water quality modelling within the Souris River basin. Report prepared by Beak Associates Consulting Ltd. for Water Quality Branch, Environment Canada, Regina.

ESSA Environmental and Social Systems Analysts Ltd. 1991. A strategy for monitoring the quality of groundwater in the Regina region. Tech. Rept. WQ139. Water Quality Branch, Saskatchewan Environment and Public Safety, Regina.

Falconer, I.R., M.T.C. Runnogar, A.R.B. Jackson, and A. McInnes. 1983. The occurrence and consequences of blooms of the toxic blue-green alga *M. aeruginosa* in eastern Australia. Toxicon. Suppl. 3: 119-21.

Golder Associates. 1987. Water quality study of Regina aquifers. Vols. 1 and 2. Prepared for Saskatchewan Environment and Public Safety, Regina.

Health and Welfare Canada. 1989. Guidelines for Canadian drinking water

quality. 4th ed. Prepared by the Federal-Provincial Subcommittee on Drinking Water for the Federal-Provincial Advisory Committee on Environmental and Occupational Health.

HydroQual Consultants Inc. and M.R.2 McDonald and Associates. 1990. Nutrient quality review and objectives development for the South Saskatchewan River basin. Tech. Rept. D14. Canada-Saskatchewan South Saskatchewan River Basin Study.

Mansuy, N. and R. Cullimore. 1989. Treating the source, not just the symptoms. Canadian Water Well (June): 8-9.

Maathuis, H. and G. van der Kamp. 1988. Comprehensive evaluation of groundwater resources in the Regina area. SRC Tech. Rept. No. 209. Saskatchewan Research Council, Saskatoon.

Peterson, H.G. 1989. Managing dugouts for improved water quality. *In* Proceedings 10th Western Nutrition Conference, 1-16. Univ. Saskatchewan, Saskatoon.

Peterson, H.G. and S.M. Swanson. 1988. Physical, chemical and biological warfare against algae. *In* Proceedings 40th Annual Convention of the Western Canadian Water and Wastewater Association, Winnipeg, MB, 153-61. Western Canada Water and Wastewater Association, Calgary.

Prepas, E.E., T.P. Murphy, J.M. Crosby, D.T. Walty, J.T. Lim, J. Babin and P.A. Chambers. 1990. Reduction of phosphorus and chlorophyll *a* concentrations following $CaCO_3$ and $Ca(OH)_2$ additions to hypereutrophic Figure Eight Lake, Alberta. Environ. Sci. Technol. 24(8): 1252-58.

Saskatchewan Environment. 1984. Water quality study North Saskatchewan River Prince Albert area (Autumn 1983). Tech. Rept. WPC40. Water Pollution Control Branch, Regina.

Saskatchewan Environment and Public Safety. 1989. Chemical use and distribution in the Regina aquifer region. Vol. 2. Prepared for Saskatchewan Environment and Public Safety, Regina.

Saskatchewan Environment and Public Safety. 1991a. Municipal drinking water quality objectives. Tech. Rept. WQ138. Water Quality Branch, Regina.

Saskatchewan Environment and Public Safety. 1991b. Saskatchewan state of the environment report. Public Affairs, Regina.

Saskatchewan Research Council, Prairie Farm Rehabilitation Administration and Alberta Agriculture. 1990. Farm surface water quality and supply on the prairies. Summary of workshop recommendations. 13-14 June 1990, Saskatoon.

Saskmont Engineering. 1990. Regina aquifers sensitivity mapping and land use guidelines. Tech. Rept. WQ134. Water Quality Branch, Saskatchewan Environment and Public Safety, Regina.

Sosiak, A.J. 1990. An evaluation of nutrients and biological conditions in the Bow

River, 1986 to 1988. Environmental Quality Monitoring Branch, Alberta Environment, Edmonton.

South Saskatchewan River Basin Study. 1991. Final report. Canada-Saskatchewan South Saskatchewan River Basin Study.

Stanley Associates Engineering Ltd. 1989. Protocols for the installation and sampling of monitoring wells. Report prepared for Saskatchewan Environment and Public Safety, Regina.

Tones, P.I., D.T. Waite and D.A. Fast. 1980. Report on nutrient impact on the South Saskatchewan River. Water Pollution Control Branch, Saskatchewan Environment and Public Safety, Regina.

Weagle, K. and R. Crosley. 1989. Mass loading of phosphorus to Lake Diefenbaker. Tech. Rept. D.13. Canada-Saskatchewan South Saskatchewan River Basin Study.

Rapporteur's Report

Dennis C. Windsor

The workshop was cochaired by Ray Pentland of Water Resource Consultants Ltd. and Patricia Tones of Sentar Consultants, who presented seminal papers on the subject prior to the workshop. The earnest and professional participation of the workshop delegates must be recognized; I sincerely trust that this report accurately reflects their contribution. Special note must be made of the contribution of the workshop members from North Dakota and Montana; they provided a welcome distinctive perspective.

The discussions of water quality and water quantity, while related, are presented separately.

The presentations by Ray and Pat restated the ancient problem with water supply: there is an adequate supply of water in the region; however, it usually is not located where it is wanted, it usually is not available when it is most needed, and often the quality is not as high as desired. Over time man has developed technologies and strategies to meet these challenges. Most of these solutions are short term in scope and increasing demands on the available water supply make the tried and true technology of the past less effective. The following local facts provide cause for sober consideration of our regional water supply: evaporation may exceed runoff in prairie lakes; and sewage effluent makes up the major part of the stream discharge downstream of several prairie communities.

Water Quantity and Supply

Mr. Pentland noted that there are four basic water-supply technologies — collection, storage, diversion and treatment. These techniques have had many variations over the ages but our twentieth-century technologies are just more sophisticated versions of the original schemes. Our collective strategy for water supply is not well articulated but most water managers would claim that it is based on a priority of need or use. Workshop discussions supported the validity of this strategy but challenged the reality of its application.

A recent documentary on public television provides an illustration of the state of our water-supply technology. This TV program described a reservoir which had been developed as a water supply for a community and for local industry. An exclusive resort had grown on the reservoir and the recreational benefits were widely praised. A leading railroad executive associated with the resort provided the technical expertise to manage the resort, the reservoir, its spillway and earthfill dam. This scenario clearly fits the current concept of multiple use and it appears that the water management was cooperative with nonconsumptive users having a share of control. Unfortunately, after several years of successful operation a record spring rainfall overtopped the spillway and dam, washing out the control structures, the community, and the downstream industrial and transportation facilities. More than 2,000 people drowned as the result of the failure of the Johnstown dam in 1889. I can not help but wonder how much the technology of that water collection and storage has advanced in the past 102 years.

The workshop spent considerable time discussing a major issue of water supply — allocation of the resource. The following comments were recorded:

- Allocation is rarely related to the actual supply; a maximum supply is usually used for allocations; yet technology can not accurately predict the average supply. It was also noted that there was little monitoring to confirm that there was compliance with the supply allocation.
- Allocation does not reflect the priority of use strategy. Rather a "first in time" approach is prevalent. Discussion moved to means to eliminate the dinosaurs, for example, enforcement of existing regulations, and withdrawal and reallocation of permits.
- Nonconsumptive users are often shortchanged in the allocation and management of limited water supplies. Ducks, fish, insects and cattails do not vote.
- Potential and existing water users find that water allocation is

complicated and confused by the number of involved regulatory authorities and the conflicting mandates of those agencies.

- While water obviously has value, that value is not reflected in the allocation of the resource. The delegates from the United States reported that a price was assigned to all water used in their jurisdictions but that cost may not be as high as the actual value of the water. The authorities in Canada do not appear ready to charge for common water uses such as irrigation and recreation.
- The delegates proposed that one of the most obvious ways of increasing our water supply was to conjunctively use the available resource. For example, sewage effluent can be used as an irrigation source for certain crops; heated industrial discharge can provide productive fish habitat.

Water Quality

The discussions of the water-quality technologies lead to an interesting conclusion — our technology is largely directed to treating water "dirtied" by mankind; we spend less effort attempting to keep the water clean.

The workshop did not challenge Pat Tones's statement that the major water-quality problem on the Prairies is nutrient loading from municipal waste and agricultural runoff. There was a consensus that, although this concern is evident to this group of professionals, little is being done to control and remedy the problem. Local action was reported but regional circumstances are not improving. It was suggested that this situation results from two factors: the problem is not widely recognized; and the cleanup is costly.

Individual municipalities are cautious about being the first agency to rise to the challenge. It was also noted that environmental impact assessments and licensing of new facilities require high technology and promises of full compliance while an adjacent existing plant can continue to operate in violation of the same standards.

Current technology exists to supply water for the residents and industry of the Great Plains region; however, the available technology is not being effectively applied. Many facilities and operations need to be upgraded and modernized to implement current technology.

The workshop concluded that water management for both quality and quantity has to expand from the current project- and site-specific scope to broader basin and regional perspectives.

Technologies and Strategies Currently Used to Develop or Access Water Supplies: Water-Quantity Considerations

R.S. Pentland and P. Tones

INTRODUCTION

Current technologies and strategies used to develop water supplies vary with the individual user's geographic location, water requirements, access to economic resources and social (political) situation.

The simplest technologies take advantage of the water where it happens to be located. Dipping a bucket in a flowing stream or locating a pasture near natural springs so the livestock can serve themselves are simple technologies of water supply that have been used around the world. These types of riparian water supplies are cheap but unfortunately, in an arid climatic region like the Great Plains, useful riparian water supplies are limited to a very few streams that actually flow at significant rates in all seasons.

In order for the Plains region to achieve any significant level of economic activity it was necessary to occupy more than the fringes of the few reliable streams. Four basic strategies were required: collection of water from a sufficient runoff area, storage to overcome the variable supply, diversion to move water to locations where it did not naturally occur, and treatment to make the water usable for the various purposes.

Collection

In the Plains region, evaporation and transpiration return most of the precipitation to the atmosphere. A very small portion reports as runoff or infiltrates to groundwater. In the driest parts of the region, there are large areas where no runoff reaches any major river system. Even local streams upstream of evaporation basins collect very tiny runoff volumes; as little as 1 cm of runoff occurs in some areas (Opuntia Lake West Inflow, 05GC007). Even on the northeastern fringes of the Plains, where we tend to view the water supply as generous, only about 25 percent of the precipitation reports as runoff (Fir River near Hudson Bay, 05LB007).

Similarly, groundwater recharge accounts for a tiny fraction of the

precipitation. On deep clay soils, like the Regina Plains, virtually no groundwater recharge occurs. Even on relatively porous soils like the recharge areas for Regina's aquifers, recharge is found to be less than 5 percent of precipitation. With a relatively low precipitation, 350 to 400 mm, and tiny proportions of runoff and groundwater recharge, any significant water user must collect water from a very large area.

The above comments tend to relate to the water users that require water in large quantities at a specified location. The largest user of water in the Plains region tends to be overlooked in this type of analysis. Plant growth uses the majority of the precipitation where it falls to support our dryland agriculture and wildlife resources.

Storage

Even after a user locates a sufficient runoff or recharge area to meet the requirements, the water-supply problems are not solved. Runoff and recharge only occur in brief periods of excess water availability. The spring snow melt, when five months of precipitation is released in a few days, is the most common source of excess. Occasional heavy rains also contribute. However, few water users can be satisfied with an occasional rush of water. Therefore, storage to overcome seasonal and annual variations in supply is necessary.

The storage strategy utilizes obvious technologies such as in-stream and off-stream surface reservoirs and controlled lakes. Less obvious, but still utilizing storage, is the use of wells to tap underground aquifers. In some cases the natural recharge is augmented by artificial recharge to better use this natural storage medium.

Diversion

The strategy of diversion to permit water use at locations where water does not naturally occur uses technologies such as canals, pipelines and augmentation of the flow of natural rivers. A more subtle form of diversion is the drainage of lakes or wetlands that augment the flows by reducing or eliminating the evaporation or transpiration that would otherwise occur.

Water Treatment

Water-treatment technologies vary with the quality of the raw water and the quality required by the end user. Water from most rivers does not require treatment for use in irrigation. Natural filtration processes eliminate the need for treating well water for many domestic purposes. For municipal water supplies, the treatment process usually includes some form of sedimentation, filtration and disinfection but where the raw water is particularly difficult, advanced technologies might include carbon adsorption, reverse osmosis or other processes.

Less Common Strategies

In addition to these common strategies, water supplies are also augmented by less common strategies such as recycling and reuse, water conservation, and multiple use.

Although intentional reuse of water resources has not been a common strategy, unintentional reuse is very common. Urban municipalities and many industries return about 70 percent of their water withdrawals to the stream. Irrigation systems usually include provision for return flows to surface streams and always augment groundwater supplies. These waters are typically reused downstream many times.

Planned recycling or reuse of water is becoming a more common technology. Industrial complexes such as pulp and mineral extraction mills are developing recycling, partly as a water-supply strategy but mostly as an effluent-control strategy. Effluent irrigation from urban sewage provides a water supply for a second purpose and also treats the waste. It should be noted that recycling and reuse do not necessarily extend the total water supply. Reuse extends the local use but, in terms of the broader river systems, it does not change the overall depletion. The second use occurs closer to the first but opportunities for reuse further downstream are eliminated.

The strategy of multiple use of water resources can be very effective in stretching the resource. Without any special effort, virtually every natural or artificial water body or supply system generates some multiple uses. Natural rivers and lakes support a wide variety of fish, waterfowl, plants and other organisms all of which represent use of the water. Human uses such as recreation and transportation which don't deplete the supply are also common. Virtually every water-supply project generates multiple secondary uses. Fish are particularly successful at colonizing any artificial water body.

With some planning, water-supply projects can serve a wide variety of uses. In Saskatchewan, the best example is Lake Diefenbaker which supplies water for irrigation, municipalities, industries, recreation, fish and wildlife. In addition, it provides a head pond and regulates the flow for hydroelectric generation and flood control.

In the following sections, some typical types of water use are discussed.

DOMESTIC WATER SUPPLIES

Domestic Water-Supply Technologies

An individual farmer who needs water for his household, livestock, spraying and garden usually cannot afford many options. Traditionally,

farmers have relied on local groundwater aquifers or small surface-water sources in the immediate vicinity of the farmyard. On the Prairies, the varying seasonal and annual precipitation, recharge and runoff requires that these water sources include, not only sufficient supply, but sufficient storage to overcome variability. If a local source is not available, expensive water transport becomes necessary. Hauling water by truck from a shared community source is a common practice. In a growing number of situations, pipelines to serve communities of farms are becoming available, particularly as spin-offs to larger urban or industrial supply systems.

Domestic Water-Supply Strategies

The strategies available to the rural farm domestic water user are very much limited by the economics.

A new farmstead or rural home typically spends $10,000 or more to set up a water supply and $1,000 or more per year to operate it. This compares to $1,000 to $2,000 that a new urban home might contribute to its water system and a few hundred dollars per year for operation.

A key strategy that society takes on behalf of the rural domestic user is to reserve the most readily available supplies through the allocation system. These users are given the top priority to both surface and groundwater. These are the only users who have retained traditional riparian rights to water in current legislation.

Society also participates through subsidies in lessening the financial burden. Wells and surface-storage costs are subsidized and where major water-delivery systems are developed, neighbouring rural supplies are usually connected but not expected to contribute to capital costs. Only operating costs are usually recovered.

As a result of the high costs, even after subsidies, the rural user is usually a fairly conscientious manager of demand. If you are hauling water by truck, you will not be running it down the drain wastefully. Therefore, conservation is usually a part of the rural resident's water-management strategy.

The location of the farmstead near a reliable supply would be an obvious strategy but is rarely applicable. There are many considerations that go into locating a farmstead that can override this apparent simple rule. For example, a farmer cannot establish his home on land he does not control. Traditionally, existing buildings and tree cover may also override water supply in location decisions.

Some rural municipalities require proof of a viable water supply before a building permit will be issued but this level of sophistication is rare in rural areas.

MUNICIPAL WATER SUPPLY

Municipal Water-Supply Technologies

For the customer, that is, households and commercial, institutional and industrial water users with a municipal water supply, the technology required to access a water supply is simple — turn on the tap and pay the bill.

However, that tap only works as result of sophisticated technologies of collection, diversion, storage, treatment and distribution that are achieved through the joint, usually unconscious, effort of the many customers through some type of utility.

The water utility must solve all of the same problems that the domestic user solved in terms of finding or creating a source with secure supply in spite of the usual variations in flows inherent in the semi-arid climate of the Plains region.

The city of Regina demonstrates most of the common technologies of supplying a sufficient volume of water. As a small town before the turn of the century, water was hauled from the creek or wells and distributed by pails, barrels, and so on. About 1905, the first municipal piped supply was developed based on a community well. As the city grew, the number of wells and the distance of piping water from wells expanded. The wells tap aquifers which provide storage against droughts and act as a collection system to accumulate infiltration from a large area.

With continued growth, the limit on the sustainable yield of the area's aquifers was reached by the mid-1950s. The closest reliable surface supply was determined to be Buffalo Pound Lake, 50 km to the west. The city built a treatment plant (jointly with Moose Jaw) and pipeline to divert water. The Buffalo Pound Lake project demonstrates most of the surface-water technologies. The lake is a collection point for runoff from a broad drainage area. The lake provides storage to meet varying demand with a varying supply. Buffalo Pound Lake has inadequate runoff for the demands placed on it and it therefore demonstrates an additional technology: interbasin diversion. Water has been diverted from the much larger and more reliable South Saskatchewan River to augment the natural supply at Buffalo Pound Lake, by pumping from 1958 to 1965 and by gravity release since Lake Diefenbaker filled in 1966.

Regina still uses a combination of wells, surface runoff, surface storage and interbasin diversion. The treatment of this supply varies. The groundwater receives negligible treatment while the surface water undergoes chlorination, settlement, filtration and activated carbon adsorption.

Municipal Water-Supply Strategies

Although location strategies could greatly simplify municipal water-supply technologies, in most cases water supply is a very minor attribute considered when selecting the location of an urban centre. Transportation has traditionally been a much more dominant consideration. When transportation was based on the waterways, urban centres ended up on appropriate water-supply points. However, most prairie urban centres are located on the railways. Railways sought flat terrain, resulting in poor water supplies. Fortunately, the early trains used steam and required at least a little water so minor water supplies entered the decision, but rarely were supplies sufficient for significant urban growth.

Considerations other than water continue to have greater influence on the growth of communities. This is because water is relatively cheap to transport and is less critical than other factors in urban planning.

Municipal water supplies are given a high priority in the allocation of water resources. Society, through its water legislation, places a high value on human uses of the resource.

Subsidies in the form of municipal water grants, usually a share of capital costs, have been a part of government strategies. Originally such programs were aimed at getting municipal supplies to meet health standards and encourage common standards of living. Even after these basic objectives had been largely met, the subsidies had become entrenched in traditional political expectations and became difficult to discontinue. In Saskatchewan, in recent years, they have been largely phased out or transferred into unconditional municipal grant pools; but, there is still a widely held view that some form of municipal water assistance is needed.

Managing the demand can be a very effective strategy in reducing the need for supply developments. Although demand management is a catchy expression that is often touted as a new solution, it has always been a part of prairie municipal water management. Rationing water during droughts is a common practice. Local authorities monitor well or reservoir levels and publish supply risks encouraging less use. When necessary, bylaws limit nonessential uses. More recently, programs of education have been sponsored by local and senior governments to discourage waste.

INDUSTRIAL WATER SUPPLY

Industrial Water-Supply Technologies

Most industries in the Prairies are located in urban centres and rely on

a municipal water utility for water supply. However, certain industries such as mineral extraction and thermal energy generation must locate near other inputs and develop independent water supplies.

Technologies depend on the local geography. In the North, water supplies are a minor problem since reliable surface streams and natural lakes stabilize the supply. In the dry prairie environment, few industrial sites coincide with natural reliable water supplies. If local aquifers provide storage and recharge they might be used but domestic and municipal users usually take priority for these sources. Except for a few large aquifers, the quantity of groundwater is not usually adequate for a major industry.

Surface storage to accumulate the variable runoff or diversion by pipelines or canals from reliable sources is usually required. In Saskatchewan, the large thermal power stations — Boundary, Coronach and Shand — are located near the lignite deposits which had limited local water resources. Major storage reservoirs were developed: Boundary, Cookson and Rafferty reservoirs. Many of Saskatchewan's potash mines depend on diverted water from the South Saskatchewan River, as far as 100 km away.

Industrial Water-Supply Strategies

An industry usually owns technology related to its particular area of endeavour and prefers to avoid other technologic areas if practical. Therefore, the strategy of locating in an urban centre with transport, power, communications and water supplies provided by others is a desirable strategy for many industries.

Where a major input such as a mineral for a mining operation dictates that the enterprise cannot locate within existing infrastructure, many industries will still pursue strategies to encourage establishment of utility supplies by others. However, because water utilities tend to be managed by political bodies such as municipalities or provinces, some industries tend to fear that their water-supply needs will be used to subsidize other users and, even though a multipurpose water utility might be advantageous overall, the industry strategy might preclude participation in a utility-operated supply.

IRRIGATION WATER SUPPLY

Irrigation Water-Supply Technologies

The greatest need for irrigation due to climatic conditions tends to arise in the driest area where the water supply is smallest and most unreliable.

The earliest large irrigation developments in the Canadian Great Plains occurred along the tributaries of the South Saskatchewan River in Alberta where the headwaters in the mountains provided a reliable base flow and the topography permitted gravity diversion from the rivers. In southwest Saskatchewan, the Cypress Hills similarly generate reliable water supplies from streams such as Swift Current Creek, Maple Creek, the Frenchman River and Battle Creek but on a fractional scale compared to the mountain streams. Small local irrigation projects began in this region using low technology gravity systems around the turn of the century.

As the base flows of these rivers were allocated and the benefits of irrigated agriculture were demonstrated, the next developments required storage of spring flows for use in the summer season. Diversions to move water further from its source were also developed.

Where early irrigation relied on gravity, later irrigation has utilized pumps to lift water into canals for distant delivery and in recent years, pressurized pipelines have been used.

Irrigation Water-Supply Strategies

Strategies of irrigation development have been aimed at utilizing the water to overcome the climatic deficit of precipitation. Similar strategies to other uses, including locating near the supplies, storage and diversion have been applied. Irrigated agriculture has been able to use one additional strategy. Other industries have much larger costs for inputs other than water and can therefore not afford to vary output in response to available water supplies. Water is the major input to irrigated agriculture and, to a certain extent, irrigated output can be varied in response to the variable supply. Therefore on smaller prairie streams where the flow can vary from year to year, irrigation development can exceed the reliable base flow by varying the area and depth of irrigation in response to the available supply in each year. In effect, the farmer stores his produce — forage or grain, or money from the sale of produce, instead of water, to level out the variable supply of water.

RECREATION WATER SUPPLY

A substantial portion of recreation activities tends to be water based. Water provides an aesthetic focus for recreation as well as being a key ingredient in activities such as swimming, boating and fishing.

Recreation Water-Supply Technologies

In order to accumulate sufficient quantities of water and to provide

reliable water conditions for recreation, technologies similar to other users including collection, storage, diversion and treatment are applied.

In many cases, water-supply facilities developed for other uses have been used for recreation activities. Few water bodies are specifically developed for recreation although recreation is commonly one of the uses considered in planning major water developments.

Recreation Water-Supply Strategies

A major strategy of recreation water supplies is flexibility in location. In general, recreation activity does not have to be at a specific site. In fact, for some recreational experiences the key factor is that the recreational activity is not at a specific site. That is, the urban dweller seeking a lakeshore experience is interested in "getting away." As long as the opportunity exists within a reasonable distance, the exact location is not relevant. Therefore, the recreation water user does not usually need to create new water supplies specifically for this use, recreation water use can take advantage of water resources where they exist naturally or where other users create the opportunity.

Because it was considered a secondary use, recreation tended to traditionally develop in an unplanned manner. The shoreline of lakes, rivers and reservoirs became occupied by cottages, beaches and boat-launching facilities with little planning. In the past when only a small demand existed, this random development was no problem. However, over time it became apparent that recreation was becoming a significant water use and that it was having significant impacts on other water uses. The linear development of recreation facilities around lake shores was having environmental impacts on water quality, fish and wildlife habitat, and was limiting the opportunity for future shoreline uses. The crowding of shorelines was also compromising other water use opportunities because of flood hazard and unreasonable expectations regarding stable water levels.

In recent decades, society has more closely regulated recreation developments so that this use has become more planned just as other water uses require special planning in the arid prairie environment.

CONCLUSION

Although each type of water user applies them in different ways, developing and accessing water supplies involves collecting water from a sufficiently large area to meet requirements, overcoming variation in the natural supply through storage of some form, diverting the water to the place it is needed and treatment to obtain the required quality.

Alternate Technologies and Strategies to Stretch Existing Water Supplies in the Great Plains: Water-Quantity Considerations

R.S. Pentland and P. Tones

INTRODUCTION

The assigned title for this segment of the symposium creates an interesting philosophic difficulty. If we know of alternate technologies and strategies that are viable, then we would be using them so they would not be alternatives, they would be current practice.

In the earlier presentation on current technologies, the evolution of past practices was discussed. No doubt, that evolution will continue. Therefore, this paper will address the current direction of that evolution and some of the ideas that appear to be taking root in water management.

CURRENT WATER USE

It is not commonly understood that the waters of the Great Plains region are presently fully utilized. It is not all used consumptively but virtually every drop of water that is not used consumptively flows through a hydroelectric turbine, supports aquatic life and water-based transportation and recreation. Each increment of water that is taken from the river systems for a consumptive use changes the opportunities to these existing uses.

On the small streams in southeastern Alberta and southwestern Saskatchewan irrigation, municipal, industrial and wildlife diversions consume or store all of the available supply most years. Only in occasional wetter than normal years is there more water than the consumptive demands in this region. Water administrators no longer permit new water-supply projects in this region.

This current level of heavy water-resource use was particularly well demonstrated when Old Wives Lake completely dried in recent years. Closed drainage basins are particularly good at emphasizing changes because they accumulate impacts from year to year. The recent completion of the Rafferty Dam has extended this region of essentially

full consumptive use of the water resource to encompass the upper Souris River basin.

Even the flows of the South Saskatchewan River are significantly depleted by water uses. Results of recent studies in Alberta and Saskatchewan indicate that Alberta uses about 22 percent of the natural flow on average and over 40 percent in dry years and this use is likely to average 33 percent on average and 50 percent in dry years early in the next century. Saskatchewan began developing its portion of this river more recently and is only consuming about 6 percent of the average natural flow and 11 percent of the drought year flow at present. This is likely to rise to about 10 percent of the average in the next few decades. In total about a third of the flow of this major river is removed for off-stream uses.

Beyond this driest portion of the Great Plains, the proportion of the resource that is consumed drops off. The more humid climate increases the supply and drops the demand, particularly for irrigation. Around the fringe of the Great Plains, in the parkland areas consumptive uses have insignificant impacts on the flows.

With the water resource fully allocated to consumptive use in the driest core of the Great Plains and fully used by in-stream users where it is not consumed, future economic growth, which is inevitably tied to the water to some extent will necessarily involve trade-offs among users. Society, through its governments and water managers will be making trades every time a development decision is made.

The technologies and strategies must therefore recognize an increasing competition for the resource. The methods of the past will certainly continue. It will still be necessary to collect water from large enough areas, provide sufficient storage and divert water to meet project needs when necessary projects are proposed.

However, as each unit of water is more fully used for in-stream and off-stream purposes, closer scrutiny of the trade-offs involved in each development will be necessary. Not only will the new proposal be scrutinized, but, past allocations will also have to be reviewed.

DEMAND MANAGEMENT

The technologies of demand management have been well documented in recent years and will continue to progress in the future. Details are well documented in the literature so I will not repeat them here. Rather, demand management is noted as a strategy that will play an increasing role with the increasing competition for the water resource with time.

The "nice" public relations types of demand management where urban families are encouraged to avoid waste will have the greatest

political appeal but they make relatively little difference to the overall water supply since most of the water is really just cycled through municipal systems and back to the streams. The real purposes of demand management in urban municipalities are to reduce short-term costs of providing the water and sewer system and to conserve energy and resources other than water.

Since about 90 percent of consumptive water use on the Great Plains is for agricultural irrigation, this is where demand-management strategies can be expected to be most effective. Historically, the process of reducing demand (per unit of output) has made significant progress. The earliest irrigation projects were gravity canals and gravity irrigation with attendant high losses. Conversion to higher technology sprinklers has significantly improved efficiency. The most recent major irrigation projects include pressurized pipeline delivery which eliminates major canal losses. In addition to saving water, these advances reduce unnecessary losses to groundwater and subsequent salinization.

Although these advances have saved water, it is saved at the cost of other resources, in this case pipeline materials and energy.

To demonstrate that we have not reached the limit yet, one need only look to the really dry regions of the world, such as the Middle East where crops are produced using a fraction of the water that we use per unit of produce.

Although demand management will likely be one of the most important strategies, others will also be needed.

ALLOCATION

As a frontier, the initial exploitation of the water resource progressed much like the land. First come first served was the simplest form of administration. Later, provisions were drawn up to set aside or reserve certain segments of the resource for future uses.

However, now that the resource is fully used, new methods of allocating the resource will become necessary, and, as competition increases, the term "reallocation" will become a necessary part of our strategies. "Reallocation" has been a taboo in traditional water management. Water rights have traditionally been held in perpetuity. Water rights legislation had provision for "higher" uses to expropriate "lower" uses but they were rarely if ever used.

Reallocation has been practiced regularly in the past in the case of in-stream and hydroelectric water use. In essence, each time a consumptive use is permitted, the flow for these in-stream uses is diminished. As more use of the water for recreation increases its

in-stream value and with the addition of more hydroelectric plants over time, this undefined reallocation is becoming more and more important. It should be noted that allocating water to in-stream uses is not new. As early as 1964, decisions to reserve large quantities of water for in-stream purposes were documented when Saskatchewan established a policy to assure a minimum flow of 42.5 m^2/s downstream of Gardiner Dam. This represents about one-quarter of the flow of the river in drought years and is about three times as large as all the off-stream allocations. Similarly, Alberta has established minimum flow policies on the managed rivers in southern Alberta.

How the future increases in competition should be managed can take many courses but the central themes might parallel basic political philosophies: a market system or a central-planning system could be used. In a market system, the trade-offs could be made through purchase and sale of rights to use water. In theory, a market system could maximize social welfare. Alternatively, the central-planning approach would take into account all the variables and calculate the optimum allocation.

The most likely scenario, a compromise, will incorporate features of both extremes; but, because of the broad scale of water geographically and in all sectors of the economy and environment, the central-planning philosophy will likely dominate the allocation strategies of the future.

IMPROVED STORAGE/GROUNDWATER

In the arid Plains region, surface storage of water tends to lead to a large loss due to evaporation. Future alternatives might work to reduce this loss.

Storage in groundwater systems might be one such approach. If groundwater is to be more extensively used on a sustainable basis, recharge must occur. Strategies to enhance groundwater recharge might include wetland preservation and artificial recharge. Simply drawing on groundwater and partially depleting the storage can enhance recharge by increasing downward gradients and reducing uncontrolled discharge.

IMPROVED TREATMENT

Large segments of the water resource are unsuited to many uses. As our understanding of chemical and biological processes improves, it will become economically practical to treat more difficult problems and make better use of more water sources. Advanced treatments tend to be expensive so treatment only becomes practical when other options are too expensive or other water sources are already committed to more valuable uses.

One recent example of an application of advanced treatment was demonstrated in the 1980s at Melville. Decades of study and development of traditional surface and groundwater systems had left the city with an inadequate water supply. From a quantity perspective, there was adequate groundwater nearby but it was too mineralized for municipal use. However, because all traditional supply alternatives would be more expensive, the abnormal alternative of demineralizing the groundwater was selected as the best viable option.

DROUGHT-RESISTANT CROPS AND CULTURAL PRACTICES

Although the water for dryland farming is not managed in the traditional sense, this is the largest use of water in the Plains region. Crops use over 90 percent of the precipitation reaching a typical farm field.

The crops which have been selected for the Plains region are chosen for their drought tolerance and continuing cultural research, plant breeding and crop selection have resulted in a steady growth in the yields of these crops. It is assumed that this trend to squeeze increasing yields out of the limited water resource will continue in the future.

CONCLUSIONS

Water-resource management on the Great Plains has evolved along with the society that the water supports. In the frontier era water was managed in frontier style with the settlers using the easiest and least complicated opportunities. Over time, as competition for the resource became evident and knowledge of the scarcity and variability was accumulated, more sophisticated technologies and strategies were adopted.

In recent years, as our knowledge of the water and the environment has grown, we have become more conscious of the trade-offs of water use, not only among human uses but between human and environmental uses. In order to balance the complex interrelationships it is necessary to look at the whole resource, not just individual projects. This is best accomplished by comprehensive study of river systems on a broad scale in order that projects can be evaluated within a framework that defines as many of the interactions as is practical.

The concept of drainage-basin studies was initiated in the 1960s and 1970s. Although the early basin studies lacked many of the technologies available today, they did provide valuable information to assist water-management decisions and to ensure that project impacts beyond the immediate site can be evaluated. As experience has been gained, the sophistication of planning processes has advanced and hopefully future technologies and strategies will continue to improve our ability to make the best of our limited water resources.

Rapporteur's Report

M. Mihajlovich

Stretching Water Quality

Discussion began by establishing that reliable technologies for maintaining and improving water quality already exist. The consensus of the group was that these technologies are not applied uniformly or holistically. Our workshop believed that the *single best* technology for improving and maintaining water quality on the Great Plains is basin scale planning and application of water standards.

A number of small water body quality improvement techniques were also discussed. These were: use of duckweed for algae management in farm dugouts; use of lime to manage nutrient levels in dugouts; seeding cattails on lagoon banks for nutrient management; and burning the organic matt in waterbodies for nutrient removal.

Discussion of duckweed focussed on how it controlled algae — by establishing shade and preventing photosynthesis. One difficulty in managing algae with duckweed is that it occurs in waves; thus the dugout being managed is either totally covered or not covered at all. A second drawback of duckweed is the susceptibility of this plant to drifting to one side of all but the smallest dugouts in the presence of even moderate winds.

Liming has good potential for nutrient management by precipitating phosphates out of dugout water. Hydrated lime ($CaOH_3$ not CaO_2) is applied to the surface as a slurry (100-200 mg lime/L of water). As the lime settles from the surface it takes with it phosphate contaminants. Again, it was stressed that lime is simply a stop-gap measure designed to alleviate, not solve, the nutrient problem. Lime should be used to temporarily remedy nutrient problems in dugouts, thus providing an opportunity to develop a management plan to prevent further nutrient buildup in the dugout.

Seeding cattails on the banks of effluent lagoons to provide a means of nutrient removal was roundly criticized. Cattails tend to overrun the banks of primary treatment lagoons when planted there, and often overrun the entire lagoon. Consensus was that this nutrient management strategy was more elegant in theory than it was usable in practice. Use of this technique has become too generalized, and should be confined to tertiary (or polishing) lagoons.

Fire as a means of removing nutrients from aquatic systems was

raised. Burning the organic matt found at the bottom of drawn down sloughs, lakes and other water bodies seems to have good potential for nutrient removal through volatilization. However, data is needed to document that the removal is indeed occurring.

Stretching Water Supply

Only two alternate technologies for stretching water supply were discussed, these were: snow management on a small aquifer, which was presented in detail by Kelly Fisher; and construction of a "man-made" glacier in the form of a giant ice cube near Phillipsburg, MT as a method of "smoothing the curve" of meltwater runoff. This project remains in the conceptual stages.

Preliminary Analysis of the Feasibility of Water-Conservation Programs in Rural Prairie Communities

Brian T. Abrahamson,
Gordon K. Kerster, and Donald M. Tate

INTRODUCTION

Water management on the Canadian Prairies has traditionally focussed on the supply aspects of water development, specifically the building of dams, diversion works and treatment facilities. This "supply-management" approach seeks to manage the region's water supplies to meet the requirements of an expanding society and economy. Viewed as a key to economic growth, water development across the Prairies has continually expanded as additional supplies and infrastructure have been developed to meet increasing demands. Historically, the supply-management approach used water conservation primarily as a tool to solve only short-term water-supply problems, such as the occasional drought, not as a long-term alternative to water planning and management. This approach to water management is shared by the Americans, as pointed out by Reinsner (1986) in his book *Cadillac Desert*.

The problem of scarcity has, over the past decade, become of increasing concern. Scarcity manifests itself in many ways. Two examples in the water field concern limited available capital for new developments (and its increased cost) and scarcity of new water supplies. These issues have forced the search for new alternatives, not necessarily to replace the old approaches, but rather to complement them. One new approach is termed "demand management," based on the fact that all water uses are demands which can be met (or remain unmet) through a variety of ways including the use of pricing policies, education, water metering and others. In terms of water conservation, demand management seeks to reduce water use or consumption through the promotion of more efficient water use and the elimination of water wastage (Tate 1990).

This paper presents the findings of a preliminary examination of demand-management water strategies as they relate to rural prairie communities. While numerous demand-management strategies and

technologies relate to both the rural agricultural and the rural community sectors (Postel 1987), time does not permit the authors to examine the wide range of complex variables that must be considered when applying the demand-management approach to agricultural water uses. Also, difficulties arise in trying to identify a "typical" strategy to be evaluated in terms of water savings and costs and benefits in the agricultural field, although this is certainly possible.

While volumes of information exist on municipal water conservation (Tate 1990), most of these studies pertain to larger American and Canadian urban centres. Very little data are available on the water savings, costs and benefits associated with water-conservation programs in smaller prairie communities. This raises many questions with respect to the potential impact of water conservation on these communities. Due to the semi-arid climate of the region, are prairie residents inherently water conscious compared with the rest of Canada? Would water-conservation measures have an impact on the water supply of smaller towns and villages? Would these measures be cost effective to both the individual and the community?

The authors did not attempt to provide conclusive answers to the above questions, that would require a comprehensive water-conservation pilot study which is outside the scope of this paper. Rather, the authors conducted a preliminary office analysis of the impact of water-conservation strategies on rural Saskatchewan communities to provide insight into the relative merits and effectiveness of water conservation on the Prairies and to illustrate some of the potential related costs and benefits. The results of this preliminary study are presented herein.

Study Communities

Three south-central Saskatchewan communities of varying size, Assiniboia, Gravelbourg and Avonlea, participated in this study. The authors selected the towns of Assiniboia and Gravelbourg because representatives from both towns had recently inquired about water-conservation techniques and their effectiveness. The village of Avonlea was asked to participate because the village recently undertook a meter-installation program that could provide useful information on the cost of metering and the overall impact of meters on water use. The three participating communities are within close proximity to one another which minimized the effect of climatic variability on historical water-use data.

Assiniboia

The town of Assiniboia, the largest of the study communities with a

population of 3,000, is located about 100 km (60 mi) south of Moose Jaw. The town draws its raw water from a system comprising two wells and two reservoirs, with the wells providing about one-quarter of the town's requirements. Water consumption is currently about 335 lpcd (74 gpcd).

As recommended in a 1985 report (PFRA 1985), the town raised one of the dams in 1989 to increase the system's firm supply. This development, for which the town paid $880,000 of the $1,630,000 capital cost, will provide the town's needs until the year 1993. The 1985 study also recommends a second development, involving improvements to the drainage basin, to be implemented in 1993. This second development, for which the town would be responsible for about $380,000 of the estimated $1,030,000 capital cost, will provide the town's water needs beyond the year 2010.

Assiniboia's existing sewage-treatment system consists of a primary lagoon and a secondary lagoon, both of which are marginally overloaded and should be expanded in the near future to meet current Saskatchewan Department of the Environment guidelines. Assuming the population will increase at an annual rate of 1 percent over the next twenty years, this study estimates the cost of expanding the lagoons at about $125,000. The larger lagoon system will meet the town's sewage requirements to the year 2010.

Gravelbourg

The town of Gravelbourg, located about 48 km (30 mi) northwest of Assiniboia, has a population of 1,300. The town obtains its raw water from Thomson Lake, a surface reservoir on the Wood River approximately 10 km (6 mi) south of town. The reservoir and the conveyance system to the water-treatment plant have the capacity to meet the town's demands well into the next century. Water consumption is currently about 490 lpcd (108 gpcd).

Gravelbourg's existing sewage-treatment system consists of a primary and a secondary lagoon. The secondary lagoon is overloaded and should be enlarged in the near future to meet existing guidelines. Assuming the population will increase at an annual rate of 1 percent over the next twenty years, this study estimates the existing primary lagoon will be adequate but the town should expand the secondary lagoon at an estimated cost of $75,000. This lagoon system will meet the town's sewage-treatment needs to the year 2010.

Avonlea

The village of Avonlea is located about 70 km (45 mi) northeast of Assiniboia. With a population of about 430, Avonlea is the smallest of the

three communities participating in this study. The village draws its raw water from the surface reservoir impounded by the Avonlea Dam located about 5 km (3 mi) to the southeast. The reservoir has sufficient capacity to meet the town's current and future needs. Water consumption has averaged 605 lpcd (134 gpcd) over the last five years.

Avonlea's existing sewage treatment consists of a primary lagoon. This lagoon, which is currently overloaded, should be expanded and a secondary lagoon constructed to comply with current guidelines. Assuming the population will grow at an annual rate of 1 percent over the next twenty years, this study estimates the village should expand the primary lagoon and construct a secondary lagoon at a total estimated cost of $125,000. This system should meet the village's sewage-treatment needs until the year 2010.

WATER-CONSERVATION PROGRAM

No "standard" water-conservation program exists that applies to all communities. The development of a water-conservation program for a particular community requires considerable insight into the needs and expectations of the particular community; therefore, program components may vary from one community to another.

Resources did not permit the authors to do a detailed study of all possibilities in each community. Instead, the authors contacted and visited each community, and carried out an "office" evaluation of the possible conservation measures which could be undertaken. Table 1 lists possible water-conservation strategies and identifies those considered for each of the communities participating in this office evaluation. Each of the strategies and their potential impacts are discussed in greater detail in the following sections.

The benefits of water conservation can be realized by both the community and the individual. At the community level, possible direct benefits include: cost savings due to deferred development or expansion of additional sources, delivery systems, and treatment facilities; reduced raw water treatment costs; reduced sewage-treatment costs; and reduced energy requirements for distribution. Possible direct benefits to the individual include reduced sewer and water bills, and reduced residential energy requirements to heat water.

Most of the surface-water storage developments on the Prairies are multipurpose projects. A reduction in water consumption in one sector will make more water available for use in other sectors. Although this paper deals, for the most part, with the direct benefits to the communities and their consumers, it should be noted that these regional benefits in the form of additional water available for other uses can be expected.

Table 1
Possible Water-Conservation Strategies and Those Considered for Each Study Community

Conservation Program Strategy	Avonlea	Gravelbourg	Assiniboia
Public Information			
Metering	x		
Office Audit	x	x	x
Leak Detection and Repair		x	x
Residential/Municipal Retrofits	x	x	x
Commercial/Industrial Audits			
Water-Rate Review			
Pressure Reduction			
Water Reuse			

The following sections describe each of the above listed conservation strategies as they apply to the three study communities, complete with estimated costs and benefits where applicable.

Public Information/Involvement

Consumer awareness and participation are the most critical components of any water-conservation program; no program will be successful without participation of the entire community. An ongoing information program is necessary to generate community support for conservation and to make the people aware of the relatively easy and cost-effective ways they can save water, as well as the financial benefits to both themselves and the community. The public information component can be in the form of town meetings, information inserts in water bills, delivering leaflets door-to-door, radio/television ads, and so on. Public information is a vital aspect of water-conservation programs; however, due to the wide variety of delivery methods available, it is not within the scope of this paper to quantify the related costs and benefits.

Water Metering

Installation of water meters is an essential first step to all water-conservation efforts. Not only do meters provide valuable data pertaining to water usage within the community, but billing on the basis of metered usage encourages conservation. Denver, Colorado estimated metered connections use 20 percent less water than unmetered connections, while Edmonton, Alberta estimated their metering program reduced consumption by 10-15 percent.

The village of Avonlea recently installed meters on all 198 residential and commercial connections to their system at an average cost of $150

each. After discounting the impact of annual climatic variability on the village's water use, Avonlea's meter program decreased consumption by about 20-25 percent, a reduction of 23 million litres (5 million gallons) per year or 115,000 litres (25,000 gal) per connection. Based on the village's current water rates, each connection would save about $63.00 per year in water charges with a payback period of 2.3 years.

Office Audit

The office-audit component is simply a review of available metered data to determine the efficiency of the delivery system. The difference between the volume of treated water pumped from the treatment plant and the total volume of metered water from all connections, after allowing for unmetered municipal uses such as park watering, swimming pools and skating rinks, is generally viewed as water lost through leakage. Both Regina, Saskatchewan and Calgary, Alberta attempt to restrict leakage to 10 percent of the total treated volume; however, the level of acceptable losses may vary from one community to another. Since the three study communities are all considerably smaller than Regina or Calgary, the delivery systems could be monitored more closely and the leakage might be reduced to 5 percent of the total volume of treated water. After allowing for a 5 percent municipal use, losses greater than 10 percent of the treated volume are considered unacceptable and indicate the need for a leak detection and repair program. Annual water data indicates the combination of losses and municipal use to be about 22 percent, 28 percent, and 9 percent for Assiniboia, Gravelbourg and Avonlea, respectively. Based on the criteria discussed previously, leak detection and repair programs are recommended for Assiniboia and Gravelbourg, but not Avonlea.

Leak Detection and Repair

The objective of the leak-detection and repair program is to find and repair all major leaks in order to reduce the losses through the system to an acceptable level. The cost of the leak-detection component is assumed to be a valid cost in this analysis but the cost of the actual pipe repairs is assumed to be an annual operating cost and is not considered herein. The benefits resulting from leak detection and repairs can be the reduced treatment costs or, if the demand exists, revenue generated from the sale of this additional treated water.

Based on a unit cost of $125/km ($200/mi) of pipe, the cost of leak detection is conservatively estimated at $20,000 for Assiniboia and $15,000 for Gravelbourg. Reducing the losses to 10 percent would save about 46 million litres (10.1 million gal) of treated water each year in

Assiniboia and about 42 million litres (9.2 million gal) in Gravelbourg thereby reducing annual treatment and pumping costs by about $8,100 and $5,700, respectively. The payback period would be about 2.5 years for both communities. However, if the treated water previously lost through the system were sold to consumers at current water rates, annual water revenues would increase by $42,000 in Assiniboia and $30,000 in Gravelbourg, providing a payback period of 0.5 years for both communities.

Residential Retrofits

The residential retrofit component involves the distribution and installation of household water-conservation devices. Retrofits are usually distributed in "kits" with each containing a low-flow shower head, toilet dams, leak detection dye tablets for toilets, and faucet aerators for kitchen and bathroom sinks. Kits can be purchased in quantity for about $15-20 each, and can be distributed and installed by local community organizations.

Residential water use accounts for about 70 percent of the total water demand of each of the three study communities. For the purpose of this study it is assumed that 85 percent of the annual residential water consumption occurs indoors with the following distribution: 45 percent toilet flushing, 30 percent showers and baths, 20 percent laundry and dishes, and 5 percent cooking and drinking.

A low-flow shower head will reduce average shower flows from 20 to 8 litres (4.5 to 1.8 gal) per minute. Assuming the average shower time would be a bit longer with the low-flow heads, the water savings would be about 35 litres (8 gal) per shower of which 22 litres (5 gal) would be hot water. Installation of two toilet dams per toilet will save about 7 litres (1.5 gal) per flush. Faucet aerators reduce flows from kitchen and bathroom fixtures from 14 to 9 litres (3 to 2 gal) per minute.

In all three communities, the consumption in residences with retrofits would likely be reduced by about 20 percent yielding annual water savings per household of 61,000 litres (13,250 gal) in Avonlea, 66,000 litres (14,600 gal) in Gravelbourg, and 50,000 litres (11,000 gal) in Assiniboia. The benefits to each retrofitted household would result from reduced water bills, sewer bills and energy costs. The annual saving per household was estimated to be $59 in Avonlea, $77 in Gravelbourg, and $76 in Assiniboia. The payback period for retrofits, assuming a cost of $20 per kit, would be about 0.3 years for Avonlea households and 0.25 years for those in Gravelbourg and Assiniboia.

For the purpose of this study, it is assumed 90 percent of the houses will initially be equipped with retrofits and 90 percent of these will be

retained after the first year of use for an overall acceptance rate of about 80 percent. At the community level, retrofits in 80 percent of the residences would reduce overall annual consumption and subsequent volume of sewage by 8.7 million litres (1.9 million gal) in Avonlea, 23.6 million litres (5.2 million gal) in Gravelbourg, and 40.9 million litres (9 million gal) in Assiniboia. Reduced volumes of sewage would impact on the previously discussed expansion proposals for the lagoon systems of each community.

Commercial Audits

The commercial audit component involves the analysis of all users in the commercial/industrial/municipal sector to identify ways to reduce water consumption. Although the majority of commercial accounts in the three study communities use water strictly for toilet and shower use, some use water in less conventional ways that would require specific information regarding the particular applications. It may be possible to effect a 10-40 percent reduction in commercial consumption, which currently accounts for about 30 percent of the total water use of each community. However, since audits require the inspection and evaluation of most users within the commercial/industrial/municipal sector, the costs and benefits were not quantified for the purpose of this office study.

Review of Water Rates

All three communities charge for water on the basis of a declining rate structure whereby the unit cost of water decreases with increasing consumption. This billing structure does little to encourage water conservation because the individuals conserving water subsidize the high users. The current trend is to establishing water rates with an inclining rate structure as a means of ensuring costs are distributed in a fair and equitable manner, and at the same time encouraging water conservation. As water rates are established at the local level with an understanding of the needs of the community, it is considered outside the scope of this paper to estimate the impact of a revised water-rate structure.

Pressure Reduction

It was estimated that a 200 kPa (30 psi) decrease in water pressure in the distribution system, from 550 kPa (80 psi) down to 350 kPa (50 psi), would decrease water consumption by about 3 to 5 percent. Since the three communities in this study operate their systems at about 410 kPa (60 psi), some 70 kPa (10 psi) above the target level, the impact of pressure reduction on these communities was assumed to be negligible.

Water Reuse

Water reuse involves the use of wastewater effluent in nonpotable applications such as park watering, nursery watering, sewer flushing and street cleaning. Water reuse may reduce the municipal component of the water demand; however, it is not deemed cost effective because effluent must be either trucked to the site or delivered via a separate effluent delivery system.

Summary

The impacts of the various water-conservation strategies on the three study communities, at both the community and individual level, are summarized in Table 2. A brief description of the impact on each community follows.

The installation of water meters and residential retrofits in the village of Avonlea would effect a 32 percent decrease in annual water consumption, a savings of 31.4 million litres (6.9 million gal). This reduction in annual consumption would reduce the requirements of the secondary lagoon, effecting a saving of about $30,000. Each connection would be responsible for cost of the meters and retrofits; however, the benefits are such that the payback period would be about 1.4 years.

The leak detection and repair strategy and the installation of residential retrofits would effect a 29 percent reduction in the town of Gravelbourg's annual water consumption. This 65.4 million litre (14.4 million gal) reduction in annual water use would eliminate the need to expand the lagoon system and save the community about $75,000. The town would be responsible for the $20,000 leak-detection component and could expect a payback period of 2.5 years based on lower water-treatment costs, or 0.5 years based on the sale of the treated water to others. Each household that purchases and installs a retrofit kit could expect a payback period of about 0.25 years.

The combination of leak-detection strategy and residential retrofits would reduce Assiniboia's water consumption by about 25 percent. This 86.8 million litres (19.1 million gal) reduction in annual water use would eliminate the need for the proposed expansions to both the water supply and sewage-treatment systems effecting a combined saving of $430,000. The town would be responsible for the $30,000 leak detection and could expect a payback period of 2.5 years based on lower water-treatment costs, or 0.5 years based on the sale of the treated water to others. As with Gravelbourg, each household that purchases and installs a retrofit kit could expect a payback period of about 0.25 years.

Table 2
Summary of Impacts of Water-Conservation Strategies

Item		Avonlea Population: 433	Gravelbourg Population: 1,305	Assiniboia Population: 3,001
I. Annual Water Use Before Conservation		95,900,000 litres (605 lpcd)	232,800,000 litres (490 lpcd)	367,800,000 litres (335 lpcd)
II. Water-Metering Component				
Individual				
Cost:	Meter	$150	—	—
Benefit:	Water Saving/Unit	115,000 litres	—	—
	Reduced Water Bill	$63		
Payback:		2.3 years	—	—
Community				
Benefit	Water Saving	22,700,000 litres		
III. Leak-Detection and Repair Component				
Community				
Cost:	Leak-Detection Program	—	$15,000	$20,000
Benefit:	Water Saving	—	41,800,000 litres	45,900,000 litres
	Reduced Treatment Costs	—	$5,700	$8,100
Payback:			2.5 years	2.5 years
OR				
Benefit:	Water Saving	—	41,800,000 litres	45,900,000 litres
	Increased Water Revenue	—	$30,000	$42,000
Payback:		—	0.5 years	0.5 years
IV. Residential Retrofits				
Individual				
Cost:	Kit	$20	$20	$20
Benefit:	Water Saving	61,000 litres	66,000 litres	50,000 litres
	Reduced Water Charges	$33	$48	$44
	Reduced Sewer Charges	—	—	$11
	Reduced Energy Charges	$26	$29	$21
	Total	$59	$77	$76
Payback:		0.36 years	0.25 years	0.26 years
Community				
Benefit:	Water Saving	8,700,000 litres	23,600,000 litres	40,900,000 litres
V. Total Impact of Water Conservation				
Individual				
Cost:	Meter and/or Retrofit Kit	$170	$20	$20
Benefit:	Water Saving/Household	174,000 litres	66,000 litres	50,000 litres
	Reduced Utility Charges	$122	$77	$76
Payback:		1.4 years	0.25 years	0.25 years
Community				
Cost:	Leak-Detection Program	—	$15,000	$20,000
Benefit:	Water Saving	31,400,000 litres (200 lpcd)	65,400,000 litres (140 lpcd)	86,800,000 litres (80 lpcd)
	Reduced Treatment Costs	—	$5,700	$8,100
OR				
	Increased Water Revenue	—	$30,000	$42,000
Payback:		—	2.5 or 0.5 years	2.5 or 0.5 years
VI. Annual Water Use After Conservation		64,500,000 litres (405 lpcd)	167,400,000 litres (350 lpcd)	281,000,000 litres (255 lpcd)

Table 3
A Partial Economic Analysis of the Impact of Water-Conservation Strategies on the Town of Assiniboia

Analytical Parameter	Without Conservation	With Conservation	Savings
Present Value of Capital Equipment or Conservation Program — Society's Perspective ($000)	990	35	955
Present Value of Capital Equipment or Conservation Program — Town's Perspective ($000)	435	35	400
Present Value of O&M — Both Perspectives ($000)	1,900	1,300	600
Total Present Value — Society's Perspective ($000)	2,890	1,335	1,555
Total Present Value — Town's Perspective ($000)	2,335	1,335	1,000
Total Water Use Over 20 Years (000 m^3)	8,440	6,150	2,290

ECONOMIC ANALYSIS

To examine the issue of benefits and costs in a somewhat rigorous manner, the authors considered the case of an expanded water-supply system for the town of Assiniboia. The town is considering the installation of the second stage of its water-supply system in 1993, at a total capital cost of $1,030,000 of which the town will pay $380,000. The town must also consider an expenditure, estimated at $125,000, to upgrade the sewage-treatment facilities. The economic analysis focusses on a comparison of the costs of water supply and sewage treatment to both society in general and the community, with and without water-conservation measures. It is assumed all capital construction and water-conservation strategies will be implemented in 1993. All capital and operation and maintenance (O&M) costs are expressed in 1991 present value terms based on a twenty-year period of analysis and an 8 percent discount rate. The results of the preliminary economic analysis are presented in Table 3.

The results of the preliminary economic analysis, carried out on the town of Assiniboia, indicate the adoption of the water-conservation

strategies discussed in this paper could result in significant benefits to society, the region and the town over the twenty-year study period. Conservation could effect a net financial saving of some $1.5 million to society with about $1.0 million representing a direct saving to the town. Also, some 2,300,000 m^3 of water would be available for other uses within the region.

CONCLUSIONS

The adoption of existing water-conservation strategies will reduce water consumption in smaller prairie communities and provide financial benefits to individuals, the community, the region and society in general. Implementation of conservation strategies can be much less costly than developing or expanding infrastructure, and provide relatively short payback periods of months to the individual and a few years to the community. These strategies can also extend the useful life of existing water supply and wastewater-treatment infrastructure.

While each of the three study communities, Avonlea, Gravelbourg and Assiniboia, appear to benefit from the implementation of water-development strategies, the applicability and impact of each strategy vary from one community to another. This indicates that, since the needs and expectations of every community are different, water-conservation programs should be specifically tailored for each community.

The analysis indicates water-conservation measures will have a positive effect on all aspects of water development on the Prairies; however, before they are universally incorporated into water-development planning strategies, field studies are required to verify their effectiveness. The next step could be the implementation of a pilot project involving a community audit, the conservation-program design, implementation of the appropriate strategies, and data collection and analysis. Such a pilot project could provide valuable information on the relative impact of each of the available water-conservation strategies.

BIBLIOGRAPHY

The opinions expressed in this paper are those of the authors, and not necessarily those of their respective employers.

Postel, S. 1985. Conserving water: the untapped alternative. Worldwatch Paper 67.

Reisner, M. 1986. Cadillac desert. Penguin Books, London.

Tate, D.M. 1990. Water demand management in Canada: A state of the art review. Social Science Series No. 23. Inland Waters Directorate, Environment Canada, Ottawa.

Rapporteur's Report

B. Ruggles

The group discussion focussed on three areas concerning water-conservation opportunities. These included pilot community water conservation projects, policies and education, and environmental benefits.

Pilot Projects

The paper by Abrahamson et al. identified a variety of opportunities for implementing practical water-conservation measures at three southern Saskatchewan communities. The most promising measures included metering (allows billing based on usage), leak control (reduces treatment costs and revenue losses), and residential retrofits (for example, low-flow shower heads, toilet dams, faucet aerators). These strategies are predicted to reduce annual water consumption by 25 to 32 percent which in turn would defer substantial capital expenditures required for expanded water and sewage works. Cost/benefit analyses indicated these conservation measures would have payback periods ranging from only 0.25 to 2.5 years. These benefits would be realized by individual residents and the community.

The group recommends that a full-scale pilot project be implemented by at least one of the communities evaluated. A project proposal should be prepared by PFRA and submitted to federal and provincial governments for evaluation and financial support. The Saskatchewan Round Table on the Environment and SUMA should also be approached as potential collaborators.

Implementation of Conservative Measures on a Wider Scale

The group identified several opportunities for promoting water conservation to a wider audience.

Education/Publicity/Awareness

- There are a host of existing programs already available and offered by all levels of government. These should continue. It is recommended that at the community level the most important groups are homeowners, schools and hotels/motels.
- Local service clubs can undertake projects for installing retrofits at minimal cost. Local retailers could supply the required hardware.
- The new publication "Prairie Water News" may be an excellent way to provide water-conservation education and information to these target groups.

Policy Changes

There are opportunities to modify existing policies at all levels of government to foster water conservation. Examples include: establishing the "true" price for the water resource; change from "declining" to "inclining" or at least steady rate structures for water consumption; require conservation audits as a component of ongoing utility operations, particularly when considering needs for expansion; and subsidize the costs of residential/commercial retrofits since the payback to the municipality is short-term.

Legislation

Changes in legislation/regulations are less preferred and considered a last resort if the other measures do not work. Any changes to legislation should focus on the prevention or source side first (for example, plumbing codes). Regulation downstream (for example, discharge permits) to achieve conservation is least preferred.

Environmental Benefits

Watershed Management and Protection

Maintaining the integrity of watersheds, particularly riparian ecosystems and wetlands, will pay large dividends in terms of conserving the supply and protecting quality and in providing wildlife habitat. As an example, the group discussed a fencing project on an Alberta trout stream. The fencing kept cattle away from the stream resulting in an enhanced brown trout fishery and an improvement in stream quality for a downstream water supply. More small-scale and local projects like this are needed.

Other examples of watershed protection measures presented include dugout management, pipelines for pasture lands to prevent overgrazing, and snow management. These approaches are very practical and do not require large expenditures.

Irrigation

The group noted an increasing trend towards sprinkler irrigation from traditional flood irrigation. It was recommended that all pump-irrigation projects be properly metered.

Effluent-irrigation projects are also being implemented in the southern prairie region with good success. It was recommended that all levels of government evaluate opportunities for effluent irrigation in cases where surface discharges conflict with other uses. The group also noted the use of treated effluent for wetland enhancement projects by Ducks Unlimited.

Strategies to Motivate Water Users and Managers to Adopt Alternate Technologies

Larry J. Whitney

Residents of the prairie provinces have always been faced with limited water supplies. As demands for these limited supplies have increased over the years, various measures have been taken to make additional supplies available, as well as to make use of the available water. These demands continue to increase with time and alternate technologies will be required to address the problem of ever increasing demands exceeding available supplies. Even the best alternate technologies will fail, however, if they are not adopted by water users and by water managers. Both users and managers will have to be motivated to adopt such technologies. A combination of strategies will be required.

Tradition tells us that there are two ways to motivate people: the use of carrots or incentives, and the use of sticks or rules and regulations. Carrots and sticks are still used, but today there is a new focus on awareness, partnerships, ownership, and consensus building. Let us first look at motivating the water user. Water users will adopt new technologies if they are affordable and in their self interest. One obvious way to motivate people then would be to offer them carrots or incentives. New technologies can be subsidized. For example, free water-saving devices could be offered, such as a flow-reduction washer costing a few cents. Alternatively, water-saving devices could be made available to users at nominal cost by water utilities or government. Government could also provide support for lining delivery canals, or for initiatives which would lead to more efficient application of irrigation water. Another form of carrot or incentive is recognition, which could include awards, dinners, hats, and many other examples. Another form of incentive or carrot which could be offered would be some form of tax credits.

So much for carrots, how about sticks? Water is not a free good and should be priced accordingly. Excess water use can be priced at a higher rate. For example, rates which increase with increasing use, rather than declining rates or block rates. As well, regulations could be put in place,

either at the provincial or local level, which restrict water use. Some communities have passed bylaws which only allow lawn watering on odd days or even days of the calendar. Regulations can also dictate the types of plumbing that can be used in new developments. Some years ago the State of California passed legislation requiring that only low-volume flush toilets could be used in new developments. Legislation can also be used to institute water-pricing formulas. In Manitoba, a number of years ago, water pricing was instituted by regulation for municipal and industrial water use. The municipal water pricing was subsequently withdrawn, but industrial water pricing remains. Another stick that can be used to encourage people to adopt new technologies is water-allocation policy. Such policy can dictate such things as the level and timing of withdrawal in water-rights licenses with the stick being the penalties imposed for violation of the terms and conditions of the license.

We have dealt with carrots and sticks, now let us deal with awareness. If people are properly informed and if they understand, people can become part of the solution rather than part of the problem. Most people want to do the right thing. People want to make a difference. A certain segment of society will even pay to do it. An example of this is blue box recycling in the city of Winnipeg where people pay $60 or $70 a year to have their recyclables collected. Another example is Minnesota's "adopt-a-road" program where people give of their time to keep a section of highway attractive and clean. If people are aware of the problem and believe that the problem is real then many are willing to do something to solve that problem. In a sense, it is another example of people acting in their own self-interest. Once people are aware of a problem, and can see that it is in their own interest to do something about it, then government will find it easier to enter into partnerships with people to develop solutions to problems. An example of such a partnership can be found in Manitoba under the name of the Pembina Valley Water Task Force. This is a partnership consisting of fifteen local governments, the provincial government and the federal government. These local governments saw the need to take a lead role in determining a long-term water-supply strategy for their area. They raised a substantial amount of local money and, with technical and some financial support from senior levels of government, developed a water-supply strategy for the next fifty years for the fifteen areas. They were aware of the problem and entered into partnership with government to come up with the solution.

How do you make people aware? There are many ways you can do it — through training, through workshops, or through the dissemination of informational materials. Advertising can also be a powerful tool. Do you

recall the first television ads for Participaction which compared the 30-year-old Canadian to the 60-year-old Swede? Did you know that those ads only ran six times? But look at the impact that they had because most of us remember that one advertisement some ten or twelve years later.

Another thing that we should not forget, at least those of us who work in government, is that people would sooner listen to a respected neighbour than to a government official. Therefore, governments would be wise to identify, cultivate, and promote local leaders who can then influence those in their communities.

We have talked a little about motivating water users. But how do you motivate the water managers? Training will be required if water managers are to believe that new technologies are the way to go. We also must empower our water managers. We must take off the chains and give them the ability to be flexible. We must take a look at rules, procedures and policies that tend to tie their hands and discourage initiative. As well, water managers must be encouraged to listen to what the front-line troops are saying. They have a lot to offer if we will only listen. We must also ensure that legislation and regulations are not at cross purposes. Regulations, policies, and programs must not encourage the continuation of old technologies while discouraging the adoption of new technologies. For example, although the water-rights legislation in each of three prairie provinces contains a list of water-use priorities, the basis of the legislation is first in time, first in right. To my knowledge, there is no current basis in legislation to favour a more efficient or more economically attractive use over another.

How else do you motivate water managers? One way to motivate them, is to make them accountable. Reward success, penalize failure. Further, do not penalize a manager's ability to help others adopt new initiatives by hitting his budget. If user fees are involved put the fees back into his or her budget and not into some general revenue account. Above all, support the staff that deal with the water user. If ministerial orders are required to stop abuses, issue them. Give staff a license to be innovative. Do not say it has never been done so we should not try it now. We have an example in Manitoba where an irrigator wanted to pump water into a flood-water diversion channel and impound it behind a drop structure for subsequent pumping onto his crop. Perhaps a traditional response would have been, "You cannot do that in a flood-water diversion channel." But why not? Water managers and their staff must be given the latitude to encourage the adoption of new technologies in the field. Give them their head, encourage initiative and be honest

about it. Lastly, take a look at your organizational structure. Does it stimulate initiative, or does it discourage it?

Let us call this last section "food for thought." Perhaps it is time to change water-rights legislation. No more first in time, first in right. Let us grant licenses for our limited water supplies to efficient users. Let us reallocate water supplies from the dinosaurs, with no compensation. Let us reallocate that water through a planning approach in which the people have a major role in deciding their own destiny.

What about a market system for water rights? Sure it makes a lot of people shudder, but it may be time to have a serious look at letting the market decide where the water should be allocated, while protecting essential needs.

Demand management is topical these days. But demand management means more than using water-saving devices, or encouraging efficiency of use. Demand management also means targeting users to where the water is, rather than taking the water to the user. We cannot always do it. For example, you cannot move land that is suitable for irrigation to a location next to a reliable source of water, but you certainly could target the site of a factory to a place that has ample water supplies.

What about a system of credits for water use? Not use it or lose it, but use what you need and get a tax break or cash for the remainder of your allocation.

Finally, the simplest ideas and most difficult of all to implement. Let us get all government agencies on the same wave length — the federal government, the province, the local government. That in itself will go a long way to getting the user on the same path.

Rapporteur's Report

Jim Rogers

In this session, institutional changes which might motivate water users and managers to adopt appropriate alternate technologies were discussed. The discussion narrowed down to motivating the user to change. The workshop participants generally agreed the best way to change the water user's attitude was to charge a realistic price for water and not to treat water as a free good. However, under present legislation, water managers cannot charge a royalty or a water-management fee. Also, reallocating water to improve efficiency is either difficult to do

under present regulations or politically undesirable. This brought the discussion back to motivating the water user.

Awareness of alternative technologies must be improved. A "ParticipAction" type program was suggested to motivate and inform water users. Government agencies also must inform the general public and other agencies about the alternative technologies. The problem of budget cuts, which usually affect communications and travel, was also raised.

Regulations could be changed, although they require inspection and enforcement. Regulations on implementing more efficient technologies could be put into building codes and design standards or preferred practices. The legislation would also have to include a fine structure for noncompliance and charges to recover costs of the program.

Incentives such as tax rebates, subsidies, free services (e.g., engineering, inspection, public information), loan and bond guarantees and training could be used to improve acceptance of the new technologies. However, with ever-decreasing budgets, incentives must be proven to improve the general economy before they can be approved.

Governments and their institutions must be acting in unison before the public will get the same message:

- Subsidies should apply to all technologies that demonstrate that they work. Mandates and programs of different institutions may conflict or give different messages.
- Personnel must be trained on the possibilities of alternative technologies. Again, the first cuts in spending are usually on communications, training and related travel.
- The use of new technologies usually needs a grass-roots groundswell by employees before they will be accepted and implemented.

Some suggestions were made to provide water-use and pollution credits to allow market forces to force implementation of more efficient technologies. Many organizations and people have difficulty with this concept since it is a type of license to pollute, and there are problems with inspection and the will to enforce the license.

A crisis may be needed to form the critical mass necessary to drive change. It was suggested that the government could provide the crisis through new, sweeping legislation. An example was the United States Clean Water Act introduced in 1972.

The main themes that recurred in the discussions were:

- Information on more efficient technologies must be given to the public.

- The government must get its own house in order, especially by reducing conflicting programs and introducing incentives to implement new technologies.
- A realistic price must be charged for water to motivate users to become more efficient.

Contributors

Authors

B.T. Abrahamson, P.Eng., Agriculture Canada — PFRA, Regina

R.B. Godwin, P.Eng., RBG-H_2O Co. Ltd., Regina

G.K. Kerster, P.Eng., Agriculture Canada — PFRA, Regina

R.S. Pentland, P.Eng., Water Resource Consultants Ltd., Regina

D.M. Tate, Ph.D., Environment Canada, Ottawa

P. Tones, Ph.D., Sentar Consultants, Saskatoon

L.J. Whitney, Manitoba Dept. of Natural Resources, Winnipeg

Rapporteurs

G.A. Fuller, Ph.D., University of Regina

M. Mihajlovich, DowElanco Canada Inc.

J. Rogers, Environment Canada, Regina

B. Ruggles, Saskatchewan Environment and Public Safety

D.C. Windsor, Manitoba Hydro

Editor

Don T. Waite, Ph.D., Environment Canada, Regina

Stretching Water Supplies

Alternate Technologies and Strategies

Edited by Don T. Waite

Water management practices on the Prairies can often be summed up as "drain it and dam it." Sloughs and wetlands are drained by landowners to produce more farmland. Streams are dammed to store water for future needs. Both activities are politically satisfying as they produce obvious and immediate benefits such as jobs and tangible structures. In the long term, however, these activities may not always be the best strategy for the Prairies.

Wetlands act as slow-release water-storage areas and may contribute to the recharge of surficial aquifers. Dams can only contain water when it exists. During drought, when the watershed is dry, there is nothing to store. Most reservoirs do not have the capacity to retain large enough volumes to supply water for extended drought periods.

The purpose of this symposium was to address current storage practices and to extend current technologies and understandings into the future, searching for new and viable concepts.

CPP 24/70 pp./$12.00/ISBN 0-88977-073-5